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FINAL REPORT

# ENERGY IN SOUTH AFRICA: A POLICY DISCUSSION DOCUMENT

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**EXECUTIVE SUMMARY**

This report has been prepared as a aide-memoire for policy making in energy in South Africa. An estimate has been made of the energy demand in the future of the various energy sources, the scenarios being based on economic growth rates between 3% and 5% per annum. Changes have been assumed in the future energy intensity (amount of energy required to produce a unit of economic GDP), the values varying with time and with the assumed economic growth rate.

The growth in each energy source is based on a mathematical analysis and using a top down approach since adequate details of individual energy source usage in each economic sector are not available. It is shown that the percentage of the market of each of the sources will reach approximately equal amounts as shown *in* Figure A.

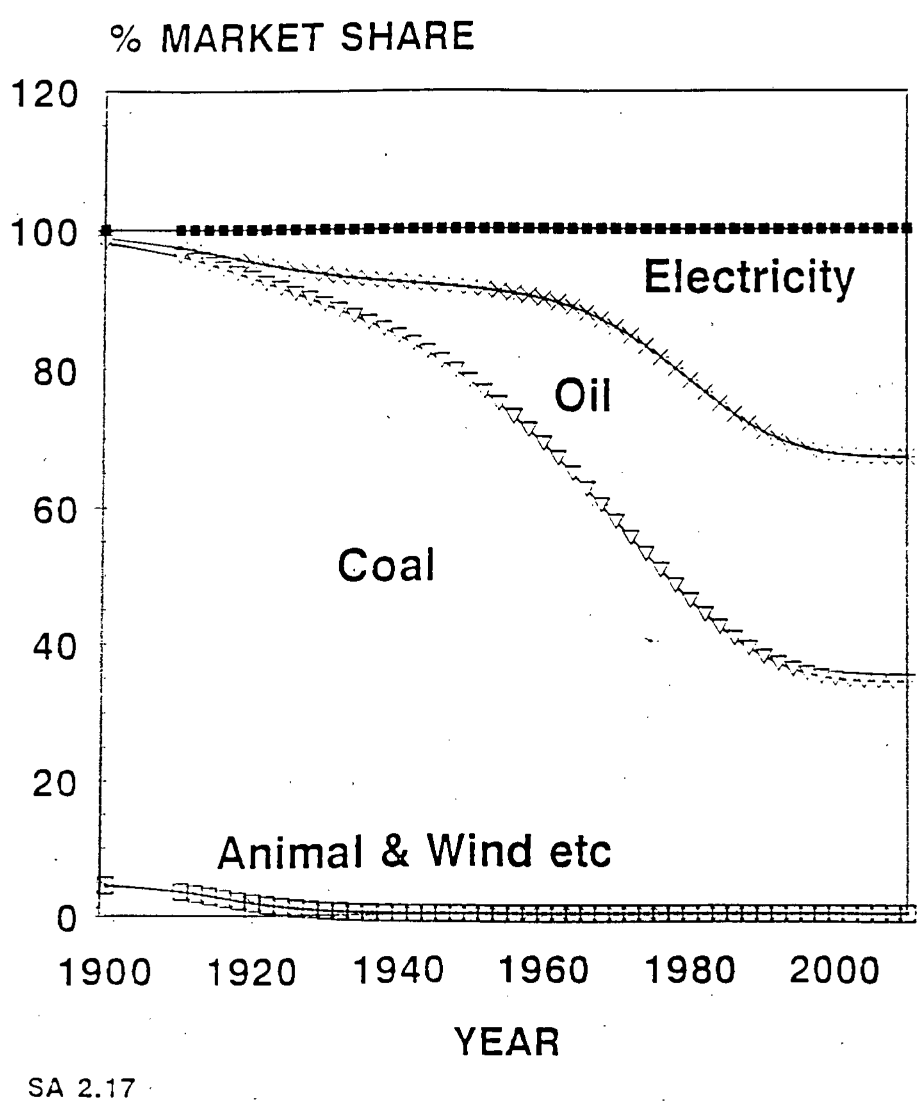


**Figure A. Energy source share of the final energy demand market**

Coal is seen as retaining a significant section of the energy market. Total coal production could reach 480 million tons per annum by the middle of the next century, depending on the world market for steam coal. Coal exports can grow to between 80 and 150 million tons per year by 2020 depending on the assumption made concerning world demand. Exports of this magnitude are not expected to significantly affect national demand if they are managed towards the end of the scenario period. One of the significant contributors to the growth in coal supply is discard coals which are currently considered to have zero value. In view of the effect of discarding these coals on the reserves, it is considered that Government intervention is required to ensure that they are used beneficially for energy production.

In view of the dominance of coal on the energy scene, research and implementation of clean-coal technology should be an aim of future policy making.

One of the most serious environmental problems in South Africa is concerned with the use of coal for domestic purposes in townships on the Highveld. It is considered urgent that a multi-point strategy, using electrification, smokeless stoves, and smokeless fuels, should be implemented to decrease the pollution levels in the townships.

Figure B shows the estimated coal consumption in terms of the various uses for the high economic growth rate scenario.

The importance of the discard coal on the country's coal resource utilisation is shown in this figure.

**Traditional fuels**

Fourteen percent of total final energy demand is made up of traditional fuels, especially fuel-wood for domestic use. Fuelwood is becoming scarce because of the uncontrolled method of its use. Whilst electrification will make some in-roads into this demand, there will be a large and increasing demand for this fuel for a long time. It is therefore important that a programme of fuel-wood provision should be instigated in the rural areas.

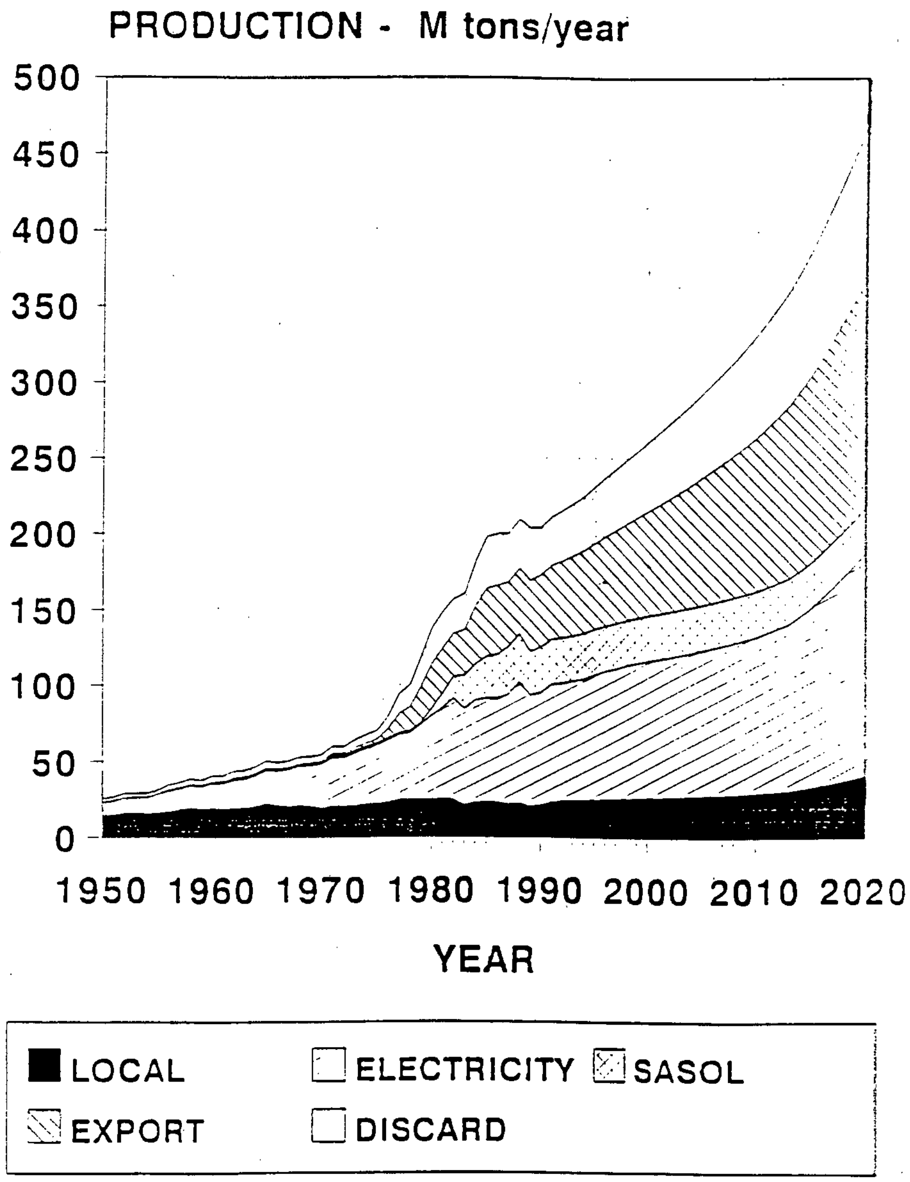


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**Figure B. Resource utilization of coal assuming that discards are not used for energy generation**

## Electricity

It is estimated that the present surplus generating capacity will turn into a shortage by about the year 2003 if no further power stations are ordered. This shortage will increase as old stations are decommissioned. Figure C shows the surplus and shortage assuming that all power stations are brought out of moth-balls, that Cahora Bassa comes back onto the system and that Kendal and Majuba are completed.

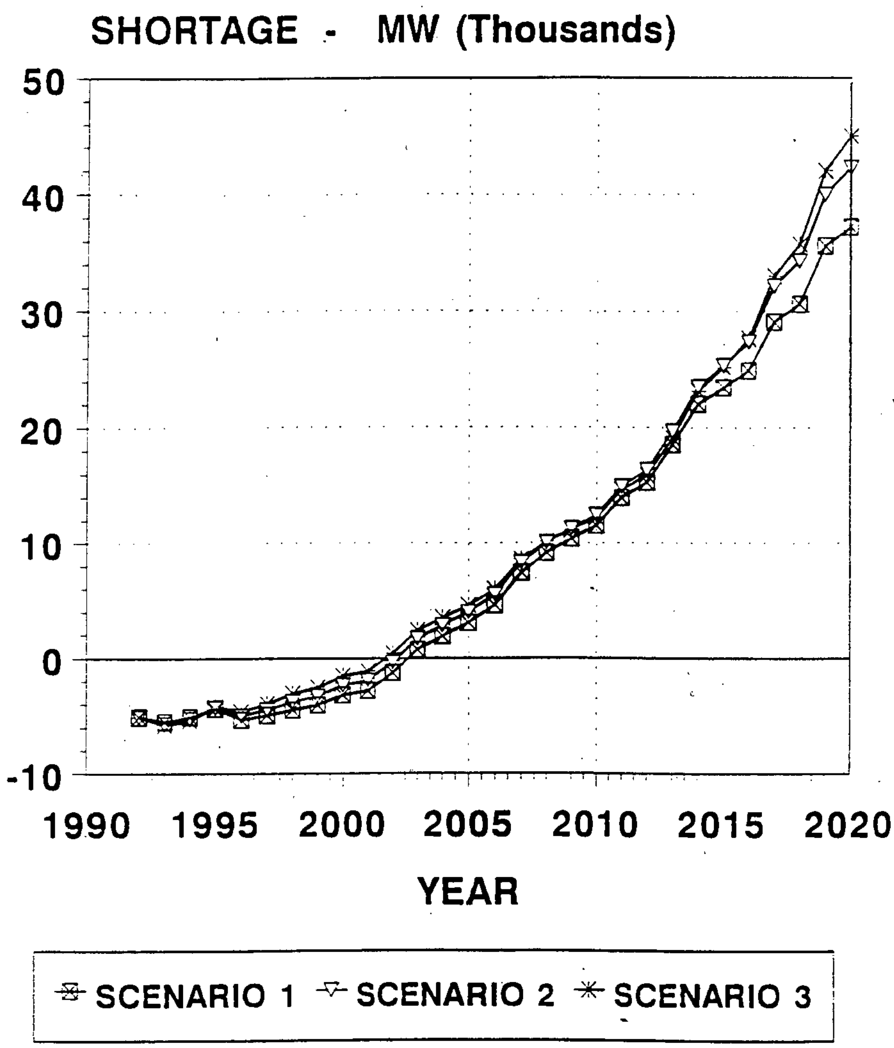


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**Figure C. Capacity surplus and shortage on the ESKOM system. (Assuming completion of Kendal and Majuba, recommissioning of all moth-balled plant and of Cahora Bassa and the future decommissioning of old plant) Scenario 1 - 3% p.a GDP growth, Scenario 2 - 4% p.a GDP, Scenario 3 - 5% p.a GDP.**

It is considered that the electricity industry has reached the stage that a restructuring should be considered. Because of the concern with the electrification programme it is considered that the distribution component of the industry should be set up as a series of regional entities with an overall organisation which would provide design and maintenance services and set standards. A second component should be a transmission organisation which would purchase power in bulk from a number of generators and including imports, and would sell to the individual distribution bodies.

In view of the need for the electrification of the under-developed areas it is considered that adequate funds be provided from central Government funds to provide electrification to those areas which are not economic in terms of the usual utility financing criteria. It is considered highly undesirable that the electricity industry should provide such funds from cross-subsidisation internally. Any subsidy for sociological or other reasons should be seen for what it is, and it should be transparent.

It is considered important that the electrical industry does not come to operate as a Government Department, but that it operates in an open and economic manner.

**Nuclear power**

Recently comments have been made concerning the economic viability of the Koeberg Nuclear Power Station. These comments could lead to demoralisation of the staff at this station, and it is important that an economic evaluation be made into its economic viability as soon as possible.

The Council for Nuclear Safety, which oversees the safety of nuclear facilities in South Africa, should be so structured that it has adequate powers to carry out its mandate. In view of the national importance of nuclear safety it is recommended that the Council should be directly responsible to the State President through a Cabinet Committee consisting of the Ministers responsible for energy and mining, environmental affairs, and economics.

**Liquid fuels**

With the end of sanctions and the end of the need for secrecy and control, it is time that the oil industry should be deregulated. However cognisance must be taken of the role of the synthetic oil industry and of local conditions. No economic case can be made for the decommissioning of Sasol or Mossgas in view of the fact that the capital for the two projects is committed. Closing the plant would therefore not affect the need to pay off the capital. As long as the operating costs are less than the alternative oil sources, these plants have to be operated in the national good. Some way has to be found to operate the plant in the most economic manner for the country.

In view of the effect of deregulation of the industry on jobs in the retail sector, it is recommended that a prohibition be placed on self-service filling stations for a period such as the next five years. Taking into account what has happened overseas with deregulation, it is considered appropriate that an embargo should be placed on the sale of fuel by bodies whose main purpose is the selling of other commodities such as food-stuffs, clothing, etc. It is believed that sales of fuel by organisations such as super-markets would undoubtedly lead to loss-leader sales of fuel. This loss would be transferred onto the price of food. Such a cross-subsidisation would result in the poorer sector of the community, who do not have cars, subsidising the richer section of the population.

In South Africa there is an imbalance between diesel fuel and gasoline demand. Compared with other countries it is considered that the tax on diesel fuel, in comparison with tax on gasoline, is excessive and should be decreased. This would have a beneficial effect on the imbalance, would be inflation reducing and would lead to a lowering of crude imports. It is considered desirable that the combi-taxi fleets should be encouraged to move towards diesel engines.

In view of the environmental damage being done by the irresponsible disposal of used lubricating oil it is considered necessary to introduce a method of financing lubricating oil recycling.

**Effective use of energy**

Significant energy and cost savings can be affected by the effective use of energy. It has been estimated that the potential cost saving to be realised by demand-side management is well over 1% of the national GDP. It is therefore important that the Government introduce a vigorous campaign for energy saving.

**Policy recommendations**

Policy in the past has been very fragmented and ad-hoc with the main driving force being energy security in the light of sanctions. It is now opportune to embark on a rational energy policy-making structure which allows for the longer term analysis of energy matters. A body such as the National Energy Council is required to carry out energy policy research and to advise the Department of Mineral and Energy Affairs on policy matters.

A number of policy matters which, it is considered, need attention are listed below:

**Coal**

(a) A policy should be developed to ensure the optimal use of discard coals in the national interest. A levy on each ton of coal discarded could be introduced and a subsidy could be given to anyone utilizing discard coal for energy production in order to make it economic.

(b) Consideration should be given to ensuring that the infrastructure is adequate in support of the long term coal export potential.

(c) An analysis should be made of the pollution levels in the Eastern Transvaal due to coal-fired power stations in order to determine under what conditions further coal-fired power stations can be constructed in this area.

(d) An independent body should be set up to monitor air pollution levels in the Eastern Transvaal, and to advise on future control needs.

(e) A strategy should be developed to minimize the effects of the use of coal for domestic applications on the Highveld.

(f) In view of South Africa's extensive reserves of coal and its large reliance on coal as an energy source, significant research is required into improving the efficiency of coal utilisation. In particular more work is required into the introduction of clean-coal technology.

**Electricity**

(g) Consideration should be given to restructuring the electricity industry in three sections - generation, transmission, and distribution. The "Transmission" section should be a wholesaler of electricity, purchasing electricity from a range of generators, including imports, and selling to distributors. The distribution sector should include an overall planning and standard setting body with regional components.

(h) The cost of nuclear power and the cost of closing Koeberg should be determined as soon as possible and a decision made on the future of Koeberg.

(i) The Council of Nuclear Safety should be given effective powers to ensure safe operation of nuclear plant. The Council should be made responsible to the State President through a Cabinet Committee consisting of the Ministers responsible for energy, economics, and environment.

(j) The externality cost of electricity generation should be estimated and internalized into the electricity price. This would ensure that the market pays the true cost of electricity.

(k) The process of electrification should receive top priority but the funding for it should come from Government sources where a project is uneconomic in utility terms.

**Liquid fuels**

(l) The petroleum industry should be deregulated subject to certain conditions such as an embargo on self-service pumps for a period of time.

(m) An embargo should be placed on the distribution of fuel by organizations which are primarily concerned with other commodities such as food, clothing, etc.

(n) A system should be introduced to ensure that used lubricating oil is recycled and not discarded in ways that are environmentally unacceptable.

(o) The tax on diesel fuel should be reduced relative to that on gasoline in order to redress the imbalance between the two fuels, and to reduce inflation.

(p) A subsidy system should be introduced to ensure that Sasol and Mossgas continue in operation but in a manner that does not impact unduly on the profitability of the petroleum industry.

**Research**

(q) Research into energy matters should be formalised to allow for continuity. Research should be funded through levies on energy and should be administered by a statutory body such as the National Energy Council.

**Effective use of energy**

(r) In view of the potentially large savings to the country, a vigorous programme to encourage effective use of energy should be introduced.

# CHAPTER 1. WORLD ENERGY SCENE

## 1.1 Introduction

Since the beginning of the 1980's the world's demand for primary energy has been rising steadily at an average of 1,9% per annum. Petroleum continued to be the main source of energy, contributing some 38% of the total energy at the end of the decade(1). Coal was the second largest energy source but its contribution fell from 34% of energy demand to 26% over the last decade. The contribution of gas rose from 19% to 21% over the decade and it is considered that gas is likely to become the main energy source of the next century.

It is estimated(2,3) that world consumption of total primary energy will grow steadily up to 2010 due to an expected continuing economic growth. Oil will continue to be the main source of energy, though its share of total consumption is likely to decrease. Energy consumption is expected to grow much more rapidly in the developing countries than in the developed countries.

In terms of total primary energy consumption the USA will remain the largest consumer followed by Europe, the CIS, China and Japan in that order. The developing countries as a group, but excluding the OPEC countries, would have a consumption similar to that of the CIS region.

Environmental matters are becoming an increasingly important factor in the energy industry and there is likely to be increasing pressure on the provision of less polluting forms of energy generation.

## 1.2 Oil supply

The increased supply of petroleum came from outside the Organization of Petroleum Exporting Countries (OPEC) and North America. The USSR was the largest world producer with an output 11,4 million barrels per day in 1990, with the USA second with an output of 8,9 million barrels per day. During the decade USA production fell but was largely offset by increased production in Mexico. The largest producer in OPEC was Saudi Arabia with an output of 5,1 million barrels per day.

The effect of the Persian Gulf War is expected to have only a short-term effect on world production. The major impact will be concerned with the recovery of the Iraq and Kuwait production. There is however significant spare capacity in the OPEC countries and therefore the absence of these two countries has not had any effect on the world situation. Kuwait production before the Gulf war was approximately 2,8 million barrels per day. It is estimated(3) that production will most probably recover by 1995 or 1996. The production from Iraq, which was approximately 3,5 million barrels per day pre-Gulf War, can be back to the same level by 1995. However Iraq production is controlled more by political considerations, including the UN sanctions, than by technical considerations. The maintenance of the oil price in spite of the Gulf war has shown that the elasticity of the oil price has decreased and that countries are discounting any changes in the oil situation.

Besides the impact of the Gulf War, the main area of concern in oil supply is the deteriorating condition of the oil fields in the Commonwealth of Independent States (CIS - previously the USSR). This region, the world's largest producer of oil, is currently going through extensive political and economic changes whose outcome is not predictable. The CIS fields have been over-exploited and a decreasing output is estimated in the medium term unless aggressive exploration is adopted. In view of the poor economic condition of the region and the already heavy investment in oil capacity, it is unlikely that the CIS will be able to maintain capacity.

The largest increase in capacity will be the Persian Gulf region where the largest reserves are available. It is highly likely that the Gulf region will have an increasing contribution to output. It is estimated that the world reliance on oil from the Gulf region will increase from a low of 29% in 1986 to 44% in 2000 and 50% in 2010.

Estimates of oil prices(3) show a gradual increase from a low in 1992. In terms of 1990 US dollars the range of prices under different scenarios varies from $17 to $32 in the year 2000, and $23 to $40 in the year 2010. At a price of around $40 alternative energy sources such as synthetic gasoline and methanol become competitive with oil and therefore this is an upper limit to the oil price in the long term. Whilst short-term excursions above this level are possible, they could not be sustained for any length of time.

## 1.3 Coal supply

At the end of the last decade coal supplied 26% of total primary world energy demand and was the second most important source after oil. Its relative position is likely to be maintained to the year 2010, though its proportional contribution is likely to decrease from 26% to 25%. The main reason for a decrease in demand will be environmental factors which will either favour other fuel sources, or will make the use of coal more expensive because of clean-up requirements which will be increasingly introduced due to environmental requirements.

At the end of the 1980's China, the USA and the USSR accounted for 56% of total coal production in the world. China was the leading producer (1 giga-ton per annum), followed by the USA (0,9 giga-tons) and the USSR (0,7 giga-tons). A comparison of the world's coal resources and the countries with the largest demand shows that there will be an increasing trade in coal world wide. The main demand will be from Europe, Japan, other Pacific Rim countries and the USA. The main reserves are as shown in Table 1 below[3]:

**Table 1. World coal reserves - million metric tons**

| **Country** | **Reserves (million tons)** |
|---|---|
| USA | 243 000 |
| CIS | 240 000 |
| China | 167 000 |
| Australia | 91 000 |
| West Europe | 78 000 |
| India | 62 000 |
| South Africa | 55 000 |
| Other countries | 98 000 |
| **Total** | **1034 000** |

Currently the main exporters are Australia, USA, and South Africa, with the first two accounting for approximately half of all internationally traded coal.

Coal production in Western Europe is expected to decrease because of the phasing out of non-competitive coal production in comparison with internationally traded coal. Subsidies that currently sustain certain coal producers will be phased out, leading to a decrease in production. Privatization of the United Kingdom electricity industry will also result in the increasing importation of cheap international coal compared with UK production.

Growing concern with pollution and specifically with acid rain and global warming will place some curbs on the increase in coal consumption, though there appears to be significant room for the development and introduction of improved "clean-coal" systems.

Consumption of coal is predicted to grow steadily over the next 20 years, maintaining its importance relative to the other energy forms. The expected world consumption patterns are shown in Table 2 below:

**Table 2. Predicted world coal consumption through to 2010 at various growth scenarios[3] - million metric tons per year**

| | 1995 | | | 2000 | | | 2010 | | |
|---|---|---|---|---|---|---|---|---|---|
| Region | Base | Low | High | Base | Low | High | Base | Low | High |
| OECD | 1734 | 1706 | 1772 | 1827 | 1776 | 1885 | 2106 | 1984 | 2188 |
| OPEC | 14 | 13 | 15 | 19 | 16 | 22 | 23 | 18 | 28 |
| Developing | 530 | 477 | 583 | 594 | 504 | 683 | 655 | 524 | 786 |
| CPEs | 2800 | 2665 | 2913 | 2940 | 2721 | 3125 | 3409 | 2933 | 377 |
| Total | 5073 | 4930 | 5207 | 5381 | 5138 | 5594 | 6194 | 5685 | 6591 |

### 1.4 Gas supply

Natural gas is expected to be the fastest growing fossil fuel up to the year 2010. Natural gas is distributed fairly widely throughout the world, making the formation of a cartel such as that of OPEC more difficult than for oil and therefore making the use of gas more acceptable from the point of view of being assured of supply. However the CIS and the Middle East account for over two-thirds of total world reserves.

The large reserves of natural gas and the advantage of gas as a less polluting fuel, compared with coal or oil, will ensure its rapid penetration into the domestic, industrial and electricity sectors. Natural gas will also be a favoured fuel for electricity generation because of the low capital cost of a gas-fueled power station and the possibility of significantly increasing the efficiency of electricity generation using a combined-cycle plant.

Gas utilization is expected to grow rapidly in the Middle East developing countries which have access to large reserves. The location of the main gas reserves in the World is given in Table 3 below:

**Table 3. World gas reserves**

| **Region** | **Reserves ($10^{12}$ $m^3$)** |
|---|---|
| CIS | 45,3 |
| OPEC(excluding Iran) | 32,9 |
| Iran | 17,0 |
| CPE(excluding CIS) | 1,5 |
| Other countries | 17,7 |
| **Total** | **114,40** |

The development of these reserves will be dependent on the ability to obtain capital. This will be a significant problem especially in developing countries.

## 1.5 Nuclear power

The nuclear industry suffered from a number of problems during the last decade. These included the heightened awareness of safety standards, especially in the aftermath of the Chernobyl accident; high economic costs in comparison with cheap fossil fuel; and the problems associated with the disposal of radioactive waste. However in the future the use of nuclear power may experience an upturn due mainly to the concern over environmental matters due to other energy sources, and especially with the concern over acid rain and global warming.

Nuclear power accounted for approximately 6% of the world final energy consumption at the end of the last decade and it is projected to maintain its share through to 2010. The overall prospects for nuclear power vary from country to country. Japan and France are two countries firmly committed to nuclear power. The Japanese government is planning to increase nuclear power's share at the expense of oil. France is already exporting significant amounts of electricity generated by nuclear means to the surrounding European countries and it is estimated that this export quantity will increase by 50% by 2010. The Pacific Rim countries, in view of their potentially high economic growth rate and lack of indigenous energy resources, are also likely to be a potential growth area for nuclear power.

It is estimated that world wide nuclear energy will grow by between 1,2% and 2% per annum between 1989 and 2010.

## 1.6 World energy demand

With an assumed world economic growth rate of around 3% per annum over the next twenty years, it is assumed that there will be a significant reduction in the overall world energy intensity ratio, due largely to improved energy utilization methods. Under these conditions it is likely that world energy demand will grow by approximately 1,3% per annum under the most likely scenario. Economic growth in the developing countries will be greater than the world average and it is likely that the energy demand growth in these countries will be approximately 2% per annum.

## 1.7 South African situation

The South African situation, which is discussed in later chapters in this report, must be seen against the developing world situation, especially in respect of the international oil price and the developing international coal trade. The impact of international concerns with the environment will also have an effect on the South African energy industry.

# CHAPTER 2. ENERGY SUPPLY AND DEMAND IN SOUTH AFRICA

## 2.1 Total final consumption

The total final energy consumption in South Africa has shown a general upward trend from 1950 to 1980 and there has been a fourfold increase in Total Final Consumption (TFC) over this period. This increase is shown in Fig. 2.1 which is drawn for total commercial energy, i.e. it does not include the traditional energy sources such as wood and crop residues. It is estimated that traditional energy contributes some 14% of total energy consumption. However this traditional energy component is used at a very low efficiency since it is usually used in open fires. If this traditional energy form was replaced by commercial energy, it would account for a lower overall fraction and this factor will be considered when making estimates of future energy requirements.

The commercial energy consumption on a per capita basis is shown in Fig. 2.2. It is of interest to compare this per capita consumption with that of other countries in Africa and with developed countries such as the UK and the USA, as shown in Table 2.1.

**Table 2.1 Total final consumption of commercial energy for selected countries (1988)[16]**

| Country | TOE (000's) | kgoe/capita |
|---|---|---|
| South Africa | 41841 | 1128 |
| Tanzania | 581 | 24 |
| Malawi | 205 | 26 |
| Mozambique | 457 | 31 |
| Kenya | 1936 | 86 |
| Zambia | 1380 | 184 |
| Zimbabwe | 2875 | 310 |
| Botswana | 415 | 343 |
| Egypt | 20190 | 390 |
| UK (1986) | 144340 | 2545 |
| USA (1986) | 1278620 | 5283 |

It is evident that South Africa is more like the developed countries than the developing countries of Africa in terms of the use of commercial energy.

Where this energy is used is shown in Fig. 2.3 for the period 1971 to 1988. This shows that over 63% of final commercial energy is used in industry and mining. The percentage of energy used in agriculture has been falling steadily, as a percentage of total energy, and currently represents less than 1% of total energy. The breakdown of total energy usage by sector is shown in Table 2.2.

The analysis of the values in Table 2.2 is complicated by the secrecy on oil products, as a result of which the oil consumption of the agricultural and residential sectors has had to be included into the "other" category.

**Table 2.2 Total final commercial energy consumption by economic sector in 1988**

| Sector | Percent of TFC |
|---|---|
| Industry/commerce | 56,1 |
| Mining | 7,6 |
| Transport | 21,1 |
| Agriculture | 0,7 |
| Residential | 6,6 |
| Other | 7,9 |

The total energy usage in the country may be correlated with economic activity, as shown in Fig. 2.4 which has been drawn as a graph of the wealth of the country on a per capita basis, using the real GDP based on the 1985 Rand, and the consumption of commercial and traditional energy on a per capita basis. There is a scatter in this figure, especially at the upper end, due to the inertia in the economic system as the economic growth has been firstly rising and then decreasing over the last decade. The growth in the per capita GDP with time is shown in Fig. 2.5.

## 2.2 Energy carriers

The main commercial energy forms in South Africa are coal, oil and electricity. Animal and renewable energy forms made some contribution to commercial energy demand at the beginning of the century but the contribution currently is small. Gas has only a small contribution at present. The breakdown of the total final energy market by energy carriers is shown in Fig. 2.6.

The role of coal in the final demand sector has been decreasing rapidly, falling from a total contribution of 77% in 1950 to 39% in 1988. Coal's share of the total energy has been taken over by electricity and oil products. By 1988 oil contributed 37% of total final energy and electricity had risen to a 26% share. These figures are for final energy demand and thus mask the importance of coal which is largely responsible for the electricity component of final energy and thus on a primary energy basis coal is still the most important energy form representing some 82% of total primary energy.

The sectorial mix of the various energy carriers for the two years 1933 and 1988 is shown in Table 2.3.

**Table 2.3 Commercial final energy sectorial mix (%) in 1933 and 1988**[15]

| | Electricity | Gas | Liquid | Solid Fuels | Total Fuels |
|---|---|---|---|---|---|
| **1933** | | | | | |
| Domest/agric | 1 | 0 | 1 | 20 | 22 |
| Indust/comm | 1 | 1 | 0 | 5 | 8 |
| Mining | 3 | 0 | 0 | 24 | 27 |
| Transport | 0 | 0 | 7 | 36 | 44 |
| Total | 6 | 1 | 9 | 85 | 100 |
| **1988** | | | | | |
| Domest/agric | 5 | 0 | 0 | 3 | 8 |
| Indust/comm | 13 | 1 | 13 | 33 | 60 |
| Mining | 7 | 0 | 0 | 1 | 8 |
| Transport | 1 | 0 | 23 | 1 | 25 |
| Total | 26 | 1 | 36 | 38 | 100 |

This table shows the large fall in the contribution of solid fuels and their replacement by liquid fuels and electricity. This movement has resulted from the move from coal for transport purposes to the use of oil, and to the move from coal as a prime mover to electricity or oil. Thus until the late 1950's steam power was still used for large power requirements such as the hoisting equipment on the gold mines. Now the requirement is met almost completely by electricity.

This move from solid fuel to liquid fuels and electricity is likely to continue and an estimate is made later in this report of the possible final percentage market saturation.

## 2.3 Energy and the economy

Energy usage is a strong function of the economy of a country. As economic activity increases so does the demand for energy, especially if the economic activity is largely dependent on the industrial sector. Thus countries, as they progress through the various periods of economic growth, require varying amounts of energy. The relationship between the economy and energy demand is expressed by the energy intensity index which is an index relating the amount of final energy used to produce a unit amount of GDP. This index can be on the basis of the total energy of the whole economy or it can be on a sectorial basis.

The relationship between economic growth and energy usage in South Africa has been discussed by Dutkiewicz(15) and Gielink and Dutkiewicz(16). A comparison with the annual growth rate in Gross Domestic Product and in energy consumption is shown in Fig. 2.7, whilst the growth rate and energy consumption growth rates in each sector of the economy are shown in Figs 2.8 to 2.10. There appears to be a correlation between the growth of GDP and energy usage and both these quantities have shown a general downward slope since the mid 1960's. The ratio of energy to GDP is known as "energy intensity" and the growth in overall energy intensity, expressed as kilograms of oil equivalent per Rand of GDP (based on the 1985 Rand) is shown in Fig. 2.11. It is evident that the amount of energy used per unit of GDP has been falling steadily to 1972, after which it begins to rise again. This fall is due to the changing percentages of the different economic sectors in the total economy, to improved efficiency of energy utilization, and to improvements in the efficiency of equipment using energy.

The comparison of the energy intensity in South Africa with that of a fully developed economy, that of the USA, is shown in Figs 2.12 and 2.13. It will be seen from these two figures that the shape of the intensity curve is the same, with the peak in energy intensity in South Africa occurring some thirty years after that in the USA. During the period 1950 to 1970 the USA intensity curve was virtually flat, but decreased rapidly after the oil shocks of 1973 to 1979 and is expected to decrease further under the action of environmental forces. It is expected that the South African curve, after a period of increasing intensity values, will follow the trend in the USA and in other developed countries.

## 2.4 Energy carrier saturation

It has been determined(17) that there is likely to be a saturation in the demand for the various forms of energy on a percentage basis. It has not been possible to determine the effect of any potential gas supply in South Africa, and in the calculations it has been assumed that the effect of any gas supply will be to reduce coal supply. This is not strictly true since any inroads by gas would also affect the share of liquid fuels and especially electricity in the total market. However the total effect of gas is likely to be small and therefore the errors in assuming that it impinges only on the coal consumption are not significant.

The contributions of coal, electricity, and oil to the total energy market are shown in Figs 2.14 to 2.17. These figures also show the best fit calculated curve. Good fits are evident for all three components. It is noteworthy in Fig. 2.16 that large perturbations in the supply situation, such as the 1970's energy crises, are noticeable in the comparison between actual and calculated values, but over time these local temporal effects are smoothed out with the long-term trend following the predicted values.

The total commercial energy component picture is shown in Fig. 2.17 in which is an assumed contribution from animal, wind, etc. at the beginning of the century.

The steady state final situation shows the main fuel components as follows:

**Table 2.4 Total commercial final energy - values from saturation curves**

| Component | Final Contribution (%) | Year for 99% of final | Year for Inflection |
|---|---|---|---|
| Coal + Gas | 34,0 | 2000 | 1972 |
| Oil | 33,0 | 1984 | 1964 |
| Electricity | 33,0 | 2002 | 1980 |

In the longer term the contribution of oil must decrease because of resource considerations, but this is out of the time-scale of this determination and will depend on world oil scenarios.

## 2.5 Traditional energy forms

In 1988 fuelwood consumption amounted to 6876 TOE(14), representing 14,1% of TFC of energy in South Africa. This should be compared with other countries in the sub-continent where Mozambique, for instance, has a figure of 88%, Kenya has 72%, etc.

Over half the population live on farms and in underdeveloped rural areas where wood is the principal fuel for cooking and heating. A further fifth of the population living in or near black townships also rely on fuelwood(18). However, the consumption of fuelwood per capita declines markedly from rural areas to peri-urban areas to townships, being substituted by coal in peri-urban areas and electricity and gas in a number of townships. Eberhard(19) gives the mean annual per capita consumption of firewood in 1986 in rural areas as 604 kg and in peri-urban ares as 334 kg.

Fuelwood is obtained from six sources: commercial exotic plantations, alien vegetation eradication, self-seeded exotics, woodlots, indigenous forests, and natural shrubland or woodland. The natural shrubland or woodland is the only significant source of fuelwood(18).

Fuelwood demand is exceeding supply with devastating social, economic and environmental effects. Studies have indicated growing fuelwood shortages in rural villages and women and other members of the household are having to walk increasingly further and are spending more time collecting fuelwood. Eberhard[18] estimated that if demand were to remain at 1990 levels, natural woodlands would be almost entirely denuded by the year 2020.

South Africa is experiencing increasing urbanization, especially since the abolition of the influx control laws in 1986 and the Group Areas Act in 1991. This, together with ESKOM's slogan of 'electricity for all' and the NEC's call for it to be extended to 'energy for all', has the potential for causing a major shift in energy consumption patterns in the rural and especially the peri-urban and township areas, with electricity, coal and gas increasingly substituting for fuelwood over the next few decades.

## 2.6 Forecast of energy growth

It has been shown above that there is a relationship between energy demand and economic growth. This relationship can be expressed by the energy intensity index. It is estimated that this index will follow the pattern set by the historical records of the developed countries adjusted for such factors as the decrease in the per capita usage of traditional fuels and their replacement by commercial energy used at a higher final efficiency. If the energy intensity can be estimated, then the final energy consumption will be a function of economic growth rate.

The population growth rate in South Africa has been 2.3% per annum over the last decade. However the per capita GDP has been decreasing over the last decade, as shown in Fig. 2.5. A decreasing GDP per capita over a long period of time would lead to political instability and an outflow of capital and can therefore not be countenanced as a long-term plan. Therefore the lower limit of economic growth has been taken as 1% per annum, typical of present conditions, rising to 2,5% per annum in 2020. This is termed **Scenario 1**.

**Scenario 2** has been taken as an economic growth rate of 2,3% per annum, rising to 3% per annum in 1996 and remaining constant thereafter. It is assumed that this in fact will mean a general improvement in the per capita economy since it is expected that the population growth rate will decrease during the forecast period.

**Scenario 3** assumes an economic growth rate of 2,3% per annum rising progressively to 5% in 2016. This is below the predicted average rate of 4,3% over the period 1990 to 2010 as forecast by the EIA[(3)].

The energy consumption is affected directly by the economic growth but is also affected by the changes in economic sectorial mix and by potential energy conservation measures. The energy intensity ratio, which is the ratio of energy used to produce a unit of GDP, has already been discussed in section 2.3 and the comparison is made in Figs 2.12 and 2.13, of the South African energy intensity ratio and that of the USA. The future changes in the energy intensity ratio will be affected by the growth rate in the economy. A stagnant economy will result in a constant energy intensity ratio, whilst a rapidly growing economy will result in the energy intensity ratio changing along the lines of that in developed nations. Thus a rapid economic growth will result in a rapid decrease in the energy intensity.

In line with the three scenarios postulated above, it is assumed that Scenario 1 will result in an energy intensity ratio decreasing only slowly with time. On the other hand, the economic growth of Scenario 3 should result in an energy intensity ratio decreasing at a rate comparable with that experienced in the 1960's. In addition, a rapid economic growth will allow funding of energy conservation measures which will result in a decreasing ratio in line with experience in developed countries. It has therefore been assumed that for the Scenario 3 condition the ratio could drop to approximately 70% of that in 1980. It is assumed that the energy intensity ratio for Scenario 2 is mid-way between the ratios for the other two conditions. The assumptions concerning the energy intensity ratio for the three scenarios is shown in Fig. 2.18.

In addition to the forecast of the growth in commercial energy, an estimate must be made of the role of traditional energy in the overall energy picture. It is known that there is serious stress on available fuelwood resources and it is unlikely that the available resources will stretch much further than 2000. However, there will be an increased move from traditional energy forms to commercial energy, especially as driven by political consideration in the future. It is likely also that there will be a concerted effort to improve the fuelwood situation to make it more self-sustainable.

It has been assumed for the forecast of energy requirements that the move to commercial energy forms will result in a decrease in energy demand from traditional sources to half of that presently used. It is also assumed that the increase in the demand for traditional fuels, in the absence of a move to commercial energy, would have to be in line with the population growth rate, taken as an average of 2% per annum.

The difference between the supply and demand of traditional energy forms, i.e. the move to commercial energy, is added to the commercial energy demand. However the amount transferred from traditional to commercial energy forms has been scaled down by the ratio of the energy efficiency with which traditional energy forms are used to the efficiency with which commercial energy is used for similar applications. A ratio of 4 is taken as the ratio of these two efficiencies.

It is estimated that the present use of traditional energy forms represents approximately 14% of that of commercial energy, i.e. 12% of total energy. Thus any errors made in the assumptions discussed above would have only a small effect on the energy forecast made under the scenarios postulated. Thus by the end of the forecast period (2020) the effect of the transfer of some of the traditional energy to commercial energy is estimated to make only a 3,6% difference in final consumption.

Figure 2.19 shows the growth in total final energy consumption with the three given economic growth rates. Because of the improvement in energy utilization with the fastest economic growth rate (Scenario 3), the energy demand is only around 10% greater than that for the scenario with the lowest economic growth rate.

The use of traditional energy will decrease in absolute terms and by the year 2020 it will represent less than 5% of total final consumption (traditional plus commercial).

## 2.7 Summary

South Africa has a per capita energy demand of approximately half of that of the UK and one-fifth of that of the USA. Approximately half of the final energy usage is by industry and a fifth is used in the transport sector. Coal is the main contributor to energy demand, though its contribution has been falling rapidly from a 77% contribution in 1950 to the present 38% contribution. An analysis of the saturation levels of the various energy forms shows that the final levels will be 34% for coal and gas, 33% for liquid fuels and 33% for electricity.

An analysis has been made of the future final energy demand for three economic growth rates. The first case - Scenario 1 - postulates that economic growth is sluggish, rising from a real growth of 1% per annum to a final growth of 2,5% in 2020. This scenario would result in a decreasing standard of living and would contribute to transforming South Africa into a Third World country. Scenario 2 postulates an economic growth rate varying from 2,3% per annum to 3% per annum. With an anticipated decrease in population birth rate, this scenario would lead to a slow improvement in the standard of living. The final scenario proposes a growth rate varying from 2,3% at the beginning of the forecast period to 5% towards the end of the period. The average economic growth rate is 3,6% per annum which is less than the 4,3% forecast for the developing countries of Africa.

The energy intensity ratio is assumed to be different for the different scenarios, representing the ability of the economy to make use of more efficient equipment and with the different economic sectorial mixes under the three economic growth rates assumed.

The estimated total final energy demand varies from 90 million tons of oil equivalent to 100 million. These figures are significantly lower than those of previous estimates[20] due mainly to the reassessment of the energy intensity ratio which, under a high economic growth rate scenario, is expected to decrease to 70% of the present value by the year 2020.

It is anticipated that there will be an increasing move from traditional energy to commercial energy and by the year 2020 it is estimated that traditional energy will represent approximately 5% of commercial energy compared with the present 14%. There will be a steadily worsening resource situation for fuelwood which, together with pressure to electrify as many households as possible, will lead to a decrease in traditional energy use in real terms. For the purpose of this study it has been assumed that the use of traditional energy will fall to 50% of the present value. This assumption will make a great difference to how energy is used in the developing section of the country, but it will not significantly affect the demand for commercial energy.

# CHAPTER 3. COAL

## 3.1 Introduction

South Africa is one of the largest coal-mining countries and in 1988 it was ranked sixth in terms of world production, as shown in Table 3.1[21]. However, it is evident that it is small compared with the first three countries in the table - China, USA and the USSR.

**Table 3.1 World production of coal in 1988**

| Country | Million tons | % of world |
|---|---|---|
| China | 985 | 28,1 |
| USA | 784 | 22,4 |
| USSR | 599 | 17,1 |
| Poland | 193 | 5,5 |
| India | 189 | 5,4 |
| South Africa | 183 | 5,2 |
| Australia | 176 | 5,0 |
| UK | 104 | 3,0 |
| Germany | 73 | 2,0 |

The largest exporter of coal is Australia which accounted for 26% of the world coal trade. The other significant exporters with their share of the international trade are shown in Table 3.2.

**Table 3.2 Main coal exporters with the percentage of the international trade in 1989[22].**

| Country | Tons/annum million | % of world trade |
|---|---|---|
| Australia | 113 | 26 |
| USA | 104 | 24 |
| South Africa | 40 | 9 |
| Canada | 39 | 9 |
| USSR | 34 | 8 |
| Poland | 32 | 7 |
| China | 14 | 3 |
| West Germany | 12 | 3 |
| Colombia | 10 | 2 |

China is not expected to become a significant export force in the near future as it will be trying to satisfy its own internal demand. The USSR, or the Commonwealth of Independent States (CIS) that made up the original USSR, are unlikely to be significant exporters because of the need to develop their out-dated mining industry to satisfy their own requirements. The CIS have serious shortcomings in their transport infrastructure and their mines have been heavily subsidized. When these subsidies are removed there is likely to be closure of many mines because of their antiquated mining methods, deep shafts and labour problems. Poland is also expected to decrease coal production because of the high costs of production compared with other countries.

However significant competition in the export coal market can be expected from Colombia, which is already a small exporter, and from Venezuela and Indonesia who have lately started developing their coal export potential. Indonesia claims to have 0,3% of global coal reserves and is conveniently situated to Japan. Coal can be transported directly from the mines for shipment to Japan.

## 3.2 Coal demand

Coal is used in South Africa in five main areas: for direct consumption in industry, households, etc., for electricity generation, for conversion to synthetic liquid fuels as at SASOL, for other chemical production processes, and for export.

The direct consumption of coal has fallen as a percentage of the total energy demand market, as discussed in Chapter 2, but it has nevertheless still grown in absolute terms with an average of 1,3% over the forty year period from 1950 to 1990. It has been shown in Chapter 2 that the percentage of coal in the final energy demand has been falling and that it is likely to continue falling until it reaches a saturation level of 34% of final energy demand. The role of gas in the South African energy scene is uncertain because of the lack of knowledge of the gas resource base in the country and in the surrounding countries. The impact of any large-scale utilization would decrease both the market shares of coal and of oil.

Figure 3.1 shows the coal consumption in the final energy sector using historical information(23) and the estimate of energy demand and saturation levels at the various scenarios as discussed in Chapter 2.

Figure 3.2 is a similar representation of coal requirements for electricity generation, and Figure 3.3 shows the total demand for coal in the energy sector including the final direct demand for coal, the demand for electricity generation, and the demand for SASOL. It has been assumed that the demand for coal by SASOL for the production of synthetic fuels will be constant at the 1989 levels. The coal utilization by SASOL has been obtained from the IEA energy balances[5] since no local information is available due to secrecy imposed by the Petroleum Products Act.

### 3.3 Coal reserves

Estimates of South Africa's coal resources have been confused by the lack of uniform terminology. Estimates of coal go back to the work of Wybergh in 1928, but the first significant analysis was carried out by the Coal Advisory Board[24] who differentiated between in-situ, extractable, and saleable. Table 3.3 shows the various estimates that have been made of coal resources over the years.

**Table 3.3 Coal resource estimates for South Africa**

| | Coal Reserves (million tons) | |
|---|---|---|
| | **In-situ** | **Mineable** |
| 1947 | | 11065 |
| 1969 | | 18877 |
| 1975 | | 24915 |
| 1981 | 110000 | 51000 |
| 1982 | 113329 | 57541 |

The general increase in the reserve estimates is similar to that of world oil reserves which increased over a number of years and are now approaching an asymptote. It is likely that the true South African reserves will be higher than current estimates.

Most of the in-situ coal (66%) has a calorific value of between 20 and 26 MJ/kg, and 11% is better than 26 MJ/kg. Most of the coal is of steam quality, with only small amounts, occurring sporadically mainly in north Natal, of coking coal. It is estimated that of the total coal reserves of 57 541 million tons, some 947 million are suitable for metallurgical purposes if beneficiation is employed. There are only small amounts of anthracite and reserves are estimated at 1112 million tons.

The total coal consumption between 1950 and 2020, as estimated above, will amount to approximately 7400 million tons or 13% of total reserves. While this does not include the use of coal for non-energy purposes, nor the export of coal, it appears that the coal consumption pattern predicted will not be affected by coal shortages. However it is considered that coal quality will decrease and that the cost of coal will increase.

## 3.4 Exports

Coal has been a cheap source of energy for South Africa for over 100 years. The reason for the cheapness of coal has been its abundance, the thickness of the seams being mined, and the shallow depths at which the coal seams are situated, making many of them workable by open-cast methods. In general however the coal is of poor quality with a high ash content, making it unsuitable for export purposes. Over the last decade increasing export quantities of coal have however been produced by suitable beneficiation. Such beneficiation (washing) however adds substantially to the cost.

The export market for South Africa has been constrained by external boycotts and the depressed world coal trade. In spite of these forces, South Africa's exports of coal have risen from less than 3 million tons per year in 1975 to 48,5 million tons in 1991. This growth is shown in Fig. 3.4 which indicates the effect of sanctions in the late 1970's and early 1980's, the brief recovery thereafter, and the effect of the worsening world economic situation over the last four or five years. With the relaxation of the embargoes and with an improved world economy, the export market should increase. Until recently the tonnages on the export market were regulated by the government, with licenses being awarded to individual mining houses and for specified yearly tonnages. The coal markets, both internal and external, have now been deregulated, and the export quantities will be determined by international supply and demand.

The potential for South African coal exports has been analysed by Daniel of the IEA Coal Research Organization[25]. The assessment has been carried through to 2000 using four different scenarios. These scenarios are a function of political and economic considerations. The results of these scenarios indicate that by 2000 exports could be between 60,0 and 68 million tons per annum, as shown in Fig. 3.5. The figure of 68 million tons per annum implies a 4% per annum growth rate. Whether this growth rate can be achieved and maintained is a function of a number of variables. During the period 1976 to 1985 the growth rate averaged 22%, but this was starting from a low base and also followed the opening of the Richard's Bay coal terminal. In the future exports will be affected by the state of the world market, by the number of other exporters, such as Colombia and Indonesia, and on the cost of South African export coal. Figure 3.5 shows the future coal exports if a 4% growth rate can be achieved and also if only a 2% growth is achieved. The difference by 2020 is over 60 million tons per year.

Recent forecasts of the world steam coal trade[27] show that exports are expected to rise by between 3,5% and 7,6% per annum, with an average of 5,9% to the end of the century. The forecasts predict that South Africa's exports will be between 64 and 70 million tons per year by 2000. This is in line with the analysis of Daniel.

It is expected therefore that in the medium term the export tonnages will increase somewhere along the 4% growth curve, though this could possibly fall later in the scenario period.

Richards Bay, the South African coal export harbour, is due to be increased in size to handle 53 million tons per year. It is also claimed that a further expansion to 65 million tons is possible at minimal additional cost. There is also a feasibility study being carried out for a further terminal. A venture of a group of companies, which includes SASOL, Anglovaal, Goldfields, ISCOR, etc., is aimed at a further 12 million tons per year through Richard's Bay.

In addition an improved political situation in Mozambique could result in additional quantities of coal being exported through Maputo.

## 3.5 Prices

Figure 3.6 shows the average price of coal to inland and export consumers from 1950 in constant 1985 Rands. The cost to ESKOM has been relatively constant over the last 40 years, with the 1990 price being equal to that in 1953. The cost to consumers in Cape Town is significantly higher, the difference being that due to transport from the Transvaal coal fields. The export price has been significantly higher, though the price showed slippage towards the end of the 1980's due to the penalty payment attributable to sanctions.

It is considered that the real cost of South African coal will increase with time due to two factors. Firstly, as the export quantity grows the cost of coal to inland consumers will rise asymptotically to the export price, subject to adjustment for the cost of beneficiation and transport. It is estimated that the cost of beneficiation (in 1991 terms) is approximately R9 per ton with a 70% recovery, the remaining 30% being discards[26]. The cost of transport from Witbank to the Richard's Bay terminal is currently R30 per ton. Converting these amounts to 1985 Rand and allowing for the discard quantities, the price of inland coal to break even with export coal at current prices would be around R34 per ton. This price would rise with any real increase in export coal. On the other hand, the price of coal to ESKOM is likely to be lower than the above "break-even" price because of the long-term contracts which are applicable to power station contracts. Nevertheless it is anticipated that the price of coal will, in the long term, rise by approximately 100% for inland industrial consumers and by around 60% for ESKOM (if a 40% premium is assumed for long-term contracts).

## 3.6 Resource depletion

Whether South Africa can export the amounts of coal that may be required on the world market and satisfy its own demand for coal and electricity produced from coal depends on the total size of the reserves and on the expected rate of production. There have been conflicting reports on the size of coal reserves in the past and on the period during which coal will play a significant role in the energy market.

If it is assumed that the production of coal with time will follow a "bell-shaped" curve, then there will be a period of exponential growth followed by a decrease in the rate of increase leading to a peak in production followed by a general decrease. Such a curve would translate into an "S-shaped" curve of cumulative production. Figure 3.7 has been shown to show the shape of a cumulative production curve to a total coal reserve of 60 000 million tons, i.e. 57 541 million tons of reserves at 1982 and a cumulative production of 2 400 million tons up to 1982. It will be seen that up to the present South Africa has used approximately 7% of its total mineable reserves. This will increase to around 11% by the turn of the century.

Figure 3.8 shows the same production figures but on an annual basis. With the assumed theoretical Gaussian curve, production has been below the theoretical curve up to the mid-1980's before falling back onto the Gaussian curve.

The actual mathematical shape of the curve is not important, but it is indicative of the fact that there is not likely to be a shortage of coal in the medium term, even at a greatly increased coal export trade. By around 2012 the inflection point of the curve will be reached and there will thereafter be a growing pressure on coal and a need to start the introduction of alternative energy sources.

The peak demand for coal will be reached around 2070. It is worth noting that, with the assumptions made, the production in 2150 will be the same as it is at present.

Whilst the production curve in the future will be a function of supply and demand economics, it is considered that there does not have to be any precipitous attempt to contain coal production expansion and that the export market can be an increasingly important contributor to foreign exchange.

## 3.7 Coal discards

With the forecast figures for coal consumption and export, the export quantities will reach levels equal to local demand. In view of the poor quality of South African coal and the consequent need to beneficiate it for the overseas market, the quantities of discard coal will reach proportions that will require that something constructive be done with them rather than dumping.

In 1985 it was estimated[28] that 44 million tons per year of discard coal were produced. Of this approximately 75% was from the beneficiation of export coal and the rest from beneficiation for local consumption. In terms of the export and local consumption quantities, this means that 30% of coal mined for the export market is discarded and between 15 and 25% of local demand (excluding power station coal) is discarded. It is assumed that export coal will require discarding 30% of coal mined and that local coal consumption for non-electricity generation purposes will result in a 15% discard. Discarding this amount of coal will decrease the available reserves of coal and will increase the rate of mining in the early stage of reserve depletion.

The difference between coal demand with and without coal discards is shown in Fig. 3.9 which shows the depletion rate of a total of 60 000 million tons of reserve. It is evident that the growth rate of production is greater for the case with discard coals than if the discard coal was used profitably. Peak demand is 480 million tons per year, compared with 425 million if discards are reused. Peak demand also occurs earlier - in 2050 compared with 2067. However, of more concern is the inflection date which is 2000 if discards are considered and 2011 when discards are not included or reused. Since the inflection year is that year in which there is mounting pressure for alternate forms of energy, the earlier date would give grounds for concern.

The amount of discard coal is large. The total coal discarded up to the year 2020 is estimated at 2300 million tons, which is approximately three-quarters of the total amount of coal used in South Africa up to the present day. Figure 3.10 shows coal production using the high growth rate scenario discussed previously. It is evident that discard coals are a large proportion of total coal production. It is therefore imperative that timely consideration be given to develop methods for reusing the large amounts of discards produced, and it is considered that any export programme should incorporate a means of using the discard coals for power generation.

## 3.8 Summary

South Africa has large resources of mineable coal, most of which is of steam quality. There are sufficient resources to allow a significant expansion of export coal. It is considered that once the world economy improves there will be increasing demand for South African steam coal on the world market. There is a question over South Africa's ability to retain its price competitiveness in the light of a growing demand for an increase in wages which are unlikely to be accompanied by productivity improvements in the medium term.

It is considered that if the discard coals can be reused, there will not be any pressure on the use of coal even with the large amounts of export coal considered. However the amounts of discard coals being produced are large, especially because of the export coal which needs significant beneficiation, and any coal policy must give attention to measures to make the reuse of such coal obligatory. Measures in this connection must be taken soon since the amounts of discard coal are increasing and delays in implementation of any policy in this regard would make the solution of this problem more difficult.

It is estimated that if some means is found to reuse the discard coal, the maximum coal production rate would be in the region of 425 million tons per year and this peak would be reached in about the year 2067. It is assumed in this estimate that all electricity would be based on the use of coal-fired power stations. However it is likely that a significant amount of new generation could be based on hydro-plant and gas imported from other countries. It is also likely that towards the end of the scenario period (2020) increasing use will be made of nuclear power.

# CHAPTER 4. ELECTRICITY

## 4.1 Introduction

South Africa was one of the first countries in the world to use electricity on a commercial basis. Kimberley introduced electric street lighting in 1982, only three years after Edison started supplying power in New York, and even before London had lighting.

In 1980 Kimberley commissioned its reticulation system and installed 300 kW of steam-powered generation. The other municipalities soon followed with their own systems. Johannesburg introduced electricity in 1891, Pretoria in 1892, Cape Town in 1895, Durban in 1897, East London in 1899, Bloemfontein in 1890 and Port Elizabeth in 1906 (29).

Further impetus to the spread of electricity was provided by the rapid expansion of the Witwatersrand gold fields. Mining groups combined to start power generation plant, initially to provide lights and to drive small equipment, but this spread to larger and larger equipment. The first such power company, the Rand Central Electric Company, was established in 1896.

Electricity prices were high, with the Rand Electricity Company charging 4,8 cents/kWh in 1903, which could be around 122 c/kWh in 1990 terms. A proposal was made early in the century to provide a centralized power system based on the hydro-potential of the Victoria Falls, which was expected to provide cheaper power. In October 1906 the Victoria Falls Power Company (VFP) was formed. The concept of harnessing the Zambezi was soon abandoned for technical and economic reasons and the VFP began the erection of steam-powered generation plant based on the coal of the Witwatersrand. It expanded rapidly and at one stage was the largest electricity-generating utility in the British Empire. Costs came down rapidly and by 1913 were 1,2 cents/kWh or approximately 33 cents/kWh in 1990 terms.

By 1920 there were a number of municipal electrical utilities and the VFP supplying electricity. In addition, the South African Railways were generating power for their own purposes. The Railways contracted a consulting engineer - Charles Merz - from the UK to advise on its electrification programme. After investigation he recommended that, as an alternate to the Railways generating their own power, the country should adopt a centralized system of generation and distribution to the advantage of all consumers.

Following the work of a government commission instigated to investigate the electricity supply system in the country, an Act of Parliament - Act 42 of 1922 - created a central utility which became known as the Electricity Supply Commission (ESCOM). ESCOM eventually took over the assets of the VFP and of the Railways. Since then ESCOM has operated in parallel with the various municipal electrify undertakings. It operated as a number of unconnected regional generation and distribution undertakings until the early 1970's, by which time the transmission system had grown to such a stage that all the undertakings were inter-connected. The growth in the system and the ability to build large generating units led to a significant decrease in unit costs until ESCOM could produce power cheaper than most of the municipal undertakings. Today ESKOM, as it is now known, produces 98% of the electrical generation in the country and supplies most of the demand of the municipalities.

## 4.2 Electricity usage

Total sales of electricity in South Africa grew by an average of around 8% per annum during the period 1950 to 1980, but the growth rate has been decreasing steadily since then, as shown in Fig. 4.3. The purpose for which electricity has been used has been changing steadily over that period as South Africa moves from a mining economy to a manufacturing economy. In 1960 the mining sector was the largest user of electricity, but by the end of the last decade manufacturing was by far the largest user.

It is likely that in the medium term this sectorial picture will show a continuing increase in manufacturing share, with domestic and commercial usages remaining constant and mining decreasing. Increases in the rate of urban and peri-urban electrification will not significantly change this picture. The move from mining to manufacture will, in the longer term, result in a decreasing load factor on the electricity system.

### 4.3 Generation and distribution

Whilst there are still a number of old small generating sets on the system, most of the generation is carried out by large, typically over 600 MW, coal-fired units, with a small fraction of generation coming from hydro and nuclear plant. Gas turbines are used as emergency stand-by plant. The breakdown of generating capacity on the ESKOM system is shown in Table 4.1.

**Table 4.1 Type of plant on the ESKOM system and units sent-out in 1991**

| Type of plant | Assigned-capacity | | Sent-out (1991) | |
|---|---|---|---|---|
| | MW | % | GWh | % |
| Coal-fired | 32058 | 88,5 | 35743 | 91,1 |
| Gas-turbine | 390 | 1,1 | 0 | 0,0 |
| Hydro | 540 | 1,5 | 1980 | 1,3 |
| Pumped-storage | 1400 | 3,9 | 1804 | 1,2 |
| Nuclear | 1840 | 5,0 | 9144 | 6,1 |
| Other* | 263 | 0,3 | | |
| | 36228 | 100 | 148934 | 100,0 |

* Imports from other countries

The pumped storage units quoted obtain their energy from the coal-fired plant and there is therefore an amount of double counting in the table.

It is obvious that in terms of units generated coal is the largest source, with hydro being used for peaking purposes. During 1991 ESKOM used 70,5 million tons of coal in power stations with an average thermal efficiency of 34,3%.

Besides the large growth in set-size, as shown in Fig. 4.1, there has been an increase in power station efficiency. One of the limiting factors in the construction of power plant on the Transvaal coal fields has been the availability of water for cooling. The amount of water used per unit of electricity produced has been decreasing steadily and the decrease has been accelerated by the introduction of air-cooled power stations in place of the evaporative cooling system previously employed. In future the limitation on coal-fired power station construction on the Highveld will not be governed by water availability but by the longer term limitations on coal resources and by environmental considerations.

Transmission line voltages have been rising with the increasing amounts of power being transmitted and with increasing distances. The backbone of the inter-provincial transmission system is based on 400 kV lines, of which there are some 13 000 km in service. The new high-voltage standard that is being introduced is 765 kV. There is also a DC line operating at +/- 533 kV between Pretoria and the Cahora Bassa Dam in Mozambique. With developments world wide in transmission technology, transmission limitations are not likely to affect the future developments of the electricity grid within South Africa, and even for long distance transmission beyond the borders.

The capacity of ESKOM's power stations as well as the maximum demand is shown in Fig. 4.2. There has been a significant departure between the installed sent-out rating of the plant and the maximum demand on the system since 1980, showing the effect of the worsening economic condition of the country and the lack of foreknowledge of this in ESKOM's planning. This is also illustrated in Fig. 4.3 which shows the growth in the units sold by ESKOM. It can be seen that the average growth rate of the 1960's and 1970's of over 8% per annum rapidly dropped after 1980 to the present 1 to 2% per annum. This has resulted in a large amount of reserve capacity. Figure 4.4 shows the amount of reserve capacity on the system from 1950 to 1990. From a low 10% it has now risen to 36%. Some of this reserve is required as spinning reserve, but the remainder is available for future growth. The time-scale of such growth will be discussed later in this section.

## 4.4 Price of electricity

The price of electricity will be discussed in terms of the price of ESKOM electricity since ESKOM supplies a very large component of the country's demand directly and the price of municipal electricity is often affected by the cross-subsidization between electricity prices and the municipal rates.

The real 1985 price of electricity in South Africa is shown in Fig. 4.5. The price curve shows cyclical variations but has been approximately constant over the last decade. There is evidence of a gradual, though small, fall over the last four years. The Chairman of ESKOM is on record as saying that ESKOM will maintain price increases below the national inflation rate in the medium term, though this will not be possible in the longer term. This decrease is however most probably in line with the reduced expenditure on new plant. When the economy improves ESKOM will need to increase its capital investment rate and prices could start increasing again.

One of the main components of the cost of electricity production is the cost of fuel. Figure 4.5 shows the operating cost of coal per unit of electricity sold. This figure shows that the cost of coal has been decreasing steadily over the last forty years. This cost, as a percentage of total electricity price, is shown in Fig. 4.6. The decrease has been large, from an average of around 30% in the early 1950's to the present 16%. This decrease has been caused almost entirely by an increase in the average operating efficiencies of power stations which have increased from 18,2% in 1950[30] to 34,3% in 1991[31].

The real cost of coal has remained relatively constant, as shown in Figs 4.13 and 4.14, where in the latter the coal cost is compared with the GDP deflator and with the Consumer Price Index. The cost of steam coal in South Africa is low compared with other countries, as shown in Fig. 4.15 where only Turkish steam coal is at a comparative cost and German coal for power generation is 15 times as high.

In terms of international comparisons South Africa remains one of the cheapest sources of electricity. Figure 4.7 shows the relative prices of electricity in 1990 to industrial consumers[32]. This comparison is based on average prices for the given countries. It may well be therefore that there are individual utilities in certain countries, notably New Zealand, where prices may be lower than those for South Africa, but on average South Africa has the cheapest electricity.

## 4.5 Demand

The demand at the final usage level for the various forms of energy has already been discussed in Chapter 2. Using the three scenarios and the estimated electricity saturation curve, it is possible to determine the demand for electricity. This demand is shown in Fig. 4.8 as the actual demand figures, expressed as sales of electricity and the expected demand under the assumed economic growth rates. Because of the assumptions concerning the changes in energy intensity for the three economic growth rates, the demand for electricity under the high growth assumption is significantly down on what a straight economic growth scenario would mean, and is not significantly above the low growth rate. The assumptions concerning the energy intensity changes are based on the fact that a high economic growth rate would mean significant new capital growth which would use the newest technology which would be more efficient than the existing equipment.

This can be translated into generation requirements on a maximum-demand sent-out basis by allowing for transmission losses and an assumed load factor in line with that experienced over the last decade. The result of this determination is shown in Fig. 4.9 which is the total generation requirement actual and forecast for the three growth scenarios.

Whilst this is the maximum demand requirement, it does not include an allowance for forced and routine outages. Assuming that a figure of 20% of installed capacity is scheduled for this purpose, then the final sent-out capacity requirement is as shown in Fig. 4.10. This figure also shows the installed capacity on the ESKOM system up to 1991 and the planned construction programme for the future. Included in the future capacity programme is the Lekwe power station for which contracts have not yet been placed but for which planning is so far down the line that it would be the easiest option when additional capacity is required.

From Fig. 4.10 it appears that there will be a shortage of capacity in the latter half of the next decade. This means that planning for the extra capacity after Lekwe will need to start in five years' time. No allowance has been made in these generation requirement graphs for the existing municipal power stations since they contribute only a small fraction of the required capacity and by the middle of the next decade these plants will be approaching the end of their useful life.

The difference between the installed capacity and the required sent-out requirements, i.e. the surplus or shortage of generating capacity, is shown in Fig. 4.11. This figure shows that there is little difference in the demand for the three economic growth scenarios considered because of the energy intensity assumptions already discussed. There will be a surplus of capacity up to some time between 2005 and 2008, with an exponentially increasing shortage thereafter. By 2020 the shortage will be between 16 000 and 23 000 MW.

## 4.6 Generation options

In view of the large amount of spare capacity on the ESKOM system at present, there is no need for a decision on the next generating capacity for some years yet. There is also sufficient spare capacity to allow for any short-term growth such as a possible rural electrification system.

Planned expansion for the next decade will have to come from coal-fired plant, from nuclear plant, and possibly from imported power. As discussed in Chapter 3, coal availability is unlikely to be a problem before about 2010. After that time coal will start to be expensive and in increasingly short supply. It is therefore likely that the last coal-fired plant will be constructed somewhere in the second decade of the 21st century. Thereafter increasing reliance will need to be placed on nuclear power and imported power.

The main potential import sources are hydro, from the rest of Sub-Saharan Africa, or gas from Namibia and Mozambique. By 2015 the shortage will be approximately 10 000 MW and possibly there will need to be a parallel installation of coal plant, some nuclear, and hydro-power from the region. Decisions on the mix and date of introduction are not required for another ten years and therefore there is time to carry out adequate planning.

The underlying factors affecting the choice of plant type include fuel availability, strategic considerations, environmental concerns, technical developments, and, of course, cost. The environmental factors could be important in the longer term and will be discussed in more detail later. Nuclear power is currently more expensive than the other alternatives and it is unlikely to change in the medium term unless environmental factors preclude the future development of coal-fired stations, though this decision point could be delayed by the use of "clean-coal" technology and gas.

Consideration also has to be given to the use of the discard coals considered in Chapter 3. This potential will require co-operation between the power utility and the coal mines and will need some encouragement or coercion from the Government to get it off the ground.

Nuclear power is likely to be more expensive than the alternative coal-fired plant until the cost of coal has increased in the second decade of the next century. However it is necessary to carry out planning, even at this early stage, because of the particular land requirements for nuclear installations, such as exclusion areas and low population densities. Land has to be purchased now since it may not be available in the future when required. This long-term holding of land should be included in the final cost of nuclear power, but the amounts are small relative to construction and operation costs, and are confounded by the possible profit to be made from land that has been purchased for a possible site but then becomes unnecessary.

In addition to hydro and nuclear stations there is also the possibility of using gas, especially from Namibia and Mozambique, for power generation.

### 4.7 Power imports

Imported power could be obtained from a number of Southern African countries. After the rebuilding of the transmission line power will most probably be available from the Cahora Bassa project in Mozambique in 1990 and expansion of this site is possible. Namibia is considering the construction of the Epupa power plant on the Ruacana River on the border between Namibia and Angola. Angola has already started the construction of the Capanda power station in Northern Angola. Both of these schemes are too large to be accommodated in the demand of each of the countries themselves and export to South Africa is the only outlet for this power. In addition there are potential developments on the Zambezi. However by far the largest development is that on the Zaire River where a total technical capability of 100 000 MW exists. Of this potential 40 000 MW is available from a short stretch of the river downstream of Kinshasa at the Inga Rapids. This is a relatively inexpensive, run-of-river, option.

The hydro import potential is associated with transmission line construction from the power sites. In the case of the potential from Inga, it is estimated that the cost of transmission line construction could be double that of the cost of construction of the generating capacity. It is unlikely that any decision would be made on the construction of such transmission capacity until the region had demonstrated political stability for a number of years. Thus the present warfare in Angola is likely to delay decisions on inter-connection for a number of years.

In view of the large capital expenditures required for generation and transmission capacity, the import of power has to be associated with a large quantity of imports. The total amount of imported capacity would be a function of strategic considerations. The more stable the region is politically, the higher the amount of possible imports. Also the more diverse the sources of import, the higher the amount of imports. The Cahora Bassa scheme, which has not produced any significant amount of power for the last decade, has shown the inadvisability of high import capacity under turbulent conditions.

Conventional wisdom at present is that imported power should not be greater than 8% of maximum demand. If the imported power is used as base load, then the amount of energy which could be imported is around 12% of electrical energy demand. If the region is politically stable and there are a number of sources of imports, and furthermore if the transmission system is diffuse, as opposed to a single line, then the amount of imports could be greater than the 8% quoted and could well be as high as 25%. Figure 4.12 shows one such possible scenario for imports where it has been assumed that the 8% conventional figure can rise to 10% by the end of the century, to 25% by the year 2016, and remains at 25% thereafter. Imports could then amount to 2000 MW until 1995, rising to a total of 17 000 MW by 2020. The initial amount is approximately in line with the capacity of Cahora Bassa and current imports from SWAWEK in Namibia.

Whilst the values of Fig. 4.12 represent the "allowable" imports in terms of security considerations, they do not represent the possible imports due to surplus on the system, the possible need to operate with a range of generation options, etc. Thus there is no need for any further generation capacity on the South African grid until about 2005 and no additional imports could therefore be considered until after that date. In fact the shortage considered in Fig. 4.11 does not include any provision for Cahora Bassa coming back on line. If Cahora Bassa is considered, then no additional capacity is required until around 2008. The provision of the full 17 000 MW import potential in 2020 would represent 74% of total new installed capacity and may be more than South Africa is prepared to consider in the time span of the forecast.

If Cahora Bassa is considered as the next source of imports, then the Capanda hydro-electric system in Angola, with a planned sent-out capacity of 520 MW, and the Epupa hydro scheme in Namibia[33] with a planned capacity of 1805 MW, could be accommodated in the programme from, say, 2008 to 2012. Thereafter the sizes of incremental power requirements could allow for the inclusion of significant imports from the proposed Inga system in Zaire.

This progression from imports from Angola and Namibia to imports from Zaire would also allow for an incremental development of the transmission system which would need to be designed for eventual up-grading to take the larger power capacities. This progression is likely to lead to the lowest overall cost in spite of the fact that Epupa would have a higher unit construction cost than Inga.

In addition to the schemes discussed above, there is additional hydro-capacity in many of the countries of the region. It is estimated, for instance, that the additional hydro-capacity on the Zambezi River amounts to 10 000 MW. Whilst some of this is required for capacity increases in the countries themselves, there could also be scope for exports to South Africa. In addition, there is potential for around 15 000 MW hydro-capacity in Angola, which could be tied in if a major transmission system was in existence.

Whilst emphasis has been given to imports of power based on hydro systems, there is also scope for gas-fired power plant, especially from the Kudu gas field off Namibia, and from the Pande gas fields in Mozambique. Both countries do not have the industrial base to use their gas profitably and there is therefore the potential to export gas to South Africa for industrial purposes and also to generate electricity, either in a power plant in the gas-producing countries or within South Africa, depending on the transmission cost of gas versus electricity and also depending on strategic considerations. In the case of the gas from the Namibian Kudu field, the generation of electricity is of interest since the Kudu field is nearer to the load centres in South Africa than it is to Windhoek. The Namibian gas scheme could be delayed however because it would be in competition with the Epupa hydro-scheme in terms of electricity exports to South Africa.

## 4.8 Electrification

In spite of the developed nature of the South African economy Southern Africa shares, with all the other countries on the continent, the fact that most of the population do not have access to electricity. The comparison with a selection of countries is given in Table 4.2.

**Table 4.2 Access to electricity and reliance on traditional energy in Sub-Saharan Africa (1990)[34]**

| | % of population with access to electricity | Traditional energy as % of total |
|---|---|---|
| Rwanda | 0,5 | 94 |
| Lesotho | 1,5 | 75 |
| Zaire | 2,1 | 88 |
| Malawi | 2,4 | 87 |
| Mozambique | 2,7 | 88 |
| Botswana | 3,6 | 53 |
| Ethiopia | 4,2 | 92 |
| Kenya | 5,1 | 72 |
| Zambia | 8,0 | 18 |
| Swaziland | 9,4 | 18 |
| Tanzania | 13,3 | 96 |
| South Africa | 35,0 | 14 |

In the past ESKOM and the municipalities have adopted the system where extension in electricity distribution had to be paid for by the new recipients of the supply. Because of the lack of funding the poorer sections of the population were unable to pay the extension cost and were largely left without electricity. There is a growing awareness that electricity should be accessible to "all" the people of the country both in terms of social entitlement, because electricity is an important component for education, and because access to electricity creates opportunities for economic advancement. How this should be achieved is the subject of an intensive investigation by the National Electrification Forum and will not be discussed here. However it is important to put the electricity for the under-developed sector into context.

There are at present an estimated 2,5 million households without electricity in South Africa. Since this sector represents the lower economic level of the population, it can be assumed that the provision of electricity would mean supplying less than 400 kWh per month to each household. The total electricity consumption of this sector would therefore be 12 000 GWh per annum. This represents approximately 8% of the present electricity sales in South Africa. Assuming a low load factor of say 20%, the additional maximum demand on the system would be 6900 MW. This is within the present surplus capacity on the ESKOM system. However this access to electricity will take some two decades to implement fully and the transition from traditional fuels to commercial fuels has been included in the scenarios proposed in Chapter 2.

It is unfortunate, but possibly inevitable, that the question of electrification has become politicized. In this process the generation authorities, both ESKOM and the municipalities, have become targets of action when the role of generation should be seen as divorced from that of distribution.

## 4.9 Structure of the industry

The main generation utility is ESKOM with 98% of total generation sales. With the present over-capacity on the system, it is cheaper for ESKOM to sell to the other utilities such as the municipalities than for them to generate power themselves. This situation could change when ESKOM is operating up to its installed capacity and the other utilities could again be net producers. However this situation is complicated by the advanced age of some of the generating capacity used by the smaller producers which have not been added to for the last 30 years. It is therefore likely that the spare capacity on the smaller utilities will be decommissioned in the near future. This would leave ESKOM as the only significant generator in the country. This means that ESKOM which has been a near-monopoly will become a total monopoly. The question therefore arises whether this is the best situation for the country, and whether this is an adequate structure when regional electricity interchange becomes significant.

The alternatives to a total monopoly of generation, transmission and distribution are either to have separate bodies dealing with generation and transmission as one unit and distribution as another, or to have the three functions - generation, transmission and distribution - as separate entities. In the later case the transmission authority would be the main wholesaler of electricity which it would sell to the distribution system or systems. The transmission authority would purchase electricity from the generation authority.

In the alternative system where there are three separate authorities, the distribution authorities could be structured on a regional basis each one catering for a limited area, though the area would need to be large enough to allow for economies of scale and for a sufficiently large core structure to provide the required technical and administrative skills.

If the transmission authority were the wholesaler of electricity, it could also purchase from a number of generation facilities. There could thus be room for the provision of electricity by small generators who may, for instance, have spare capacity from their own auto-generation. This would include such generators as sugar mills burning bagasse or small concerns producing electricity from renewable sources. Each of these generators would need to satisfy technical and economic criteria and the existence of long-term contracts would have to be taken into account. Such a structure would be a suitable basis for a trade in electricity on a regional basis. Such a system already operates amongst the various electricity utilities in the USA and Europe, and the resultant competition has led to increases in efficiency and decreases in cost.

Whilst such alternative structures are considered possible in the longer term, it is considered that the present structure should not be changed in the short term since it has been found to work satisfactorily. However consideration could, and should, be given to divorcing the generation and transmission facility from that of distribution where a regional structure is required. Funding of distribution should also not be left to the cross-subsidization within a single body but should be funded, where necessary, as a social factor by central government.

# CHAPTER 5. LIQUID FUELS

## 5.1 Introduction

The term liquid fuels includes transport and industrial combustion fuels. In South Africa the term includes petroleum-based products, oil-from-coal products produced by SASOL, and the oil-from-gas products produced by MOSSGAS.

Discussion in this field has, until recently, been complicated by the secrecy generated by the Petroleum Act which made the obtaining of any reliable information on the source or quantities of petroleum products or the production of SASOL or MOSSGAS fuels, a criminal offence. Whilst there could have been a good reason for protecting information on the sources of petroleum during the sanctions era, the protection of knowledge of product quantities had no logical basis. Anyone who required to know local demand for strategic reasons could have obtained a "ball-park" figure from various sources, whilst local researchers were denied this knowledge. Energy statistics were produced by the International Energy Agency (IEA), and now that secrecy has been reduced it can be calculated that the IEA petroleum usage figures were, in general, within 5% of the correct figure up to 1982 and within an average of 12% from 1982 to 1992. The secrecy therefore had no effect for those wishing to consider the effect of oil sanctions on South Africa, but it did stifle research and debate on energy.

The main use of liquid fuels in South Africa is as a transport fuel, with gasoline and diesel accounting for 83,3% of total liquid fuel consumption in 1992. Aviation fuel, in the form of gasoline and jet fuel, accounted for another 6,4%. Thus transport fuels make up 90% of total. In addition, there is significant use of heavy and light oils for combustion purposes in industry and in the commercial sector. A further use which is small in quantity but significant in terms of domestic consumption is the use of paraffin as a cooking and heating fuel in the developing sector.

## 5.2 Usage

Total consumption of liquid fuels has been increasing steadily, as shown in Fig. 5.1. The annual growth rate (Fig. 5.2) over the period 1950 to 1972 was nearly 8% per annum. The growth rate decreased rapidly after 1973 due to the effect of the first oil crisis. This, together with the second oil crisis in 1979 and the economic depression in South Africa, caused the liquid fuel consumption to decrease during the period 1978 to 1983, with only a modest growth rate of 3,3% per annum over the last decade.

The main components of consumption have been gasoline and diesel, as shown in Fig. 5.3. Together these two components account for over 80% of total liquid fuel usage. Due to the low cost of coal, the demand for heavy fuel oil is small. The breakdown in component usage in 1992 is given in Table 5.1.

**Table 5.1 Liquid fuel final consumption in 1992 (tons oil equivalent)[35]**

| | Tons oil equivalent | Percentage |
|---|---|---|
| Gasoline | 7091 | 52,1 |
| Diesel | 4255 | 31,2 |
| Illum. paraffin | 574 | 4,2 |
| Aviation fuel | 874 | 6,4 |
| LPG | 299 | 2,2 |
| Heavy fuel oil | 492 | 3,6 |
| Other | 34 | 0,3 |
| Total | 13619 | 100,0 |

Figure 5.4 shows the relationship between the consumption of gasoline and diesel fuel against time, and Figure 5.5 shows consumption against the GDP in real terms. In spite of the downturn in the economy, the usage of gasoline has been increasing after an initial flattening out of the curve in the aftermath of the oil crises of the 1970's. On the other hand the consumption of diesel fuel is strongly influenced by the economy, as is to be expected.

The demand for transport by the population has been growing steadily, as shown in Fig. 5.6 which shows the number of registered passenger vehicles per 1000 head of population from 1930. The decreases in the vehicle population density during the World War 2 days and during the oil crisis period in the 1970's are evident, but they do not significantly change the long-term demand for transport. The increase in vehicle population has not necessarily been matched by new car sales since Figure 5.7 shows that new car sales have decreased significantly in the mid-1980's, implying that passenger vehicles are being kept for longer. The ratio of new vehicle sales to the total vehicle population in the passenger category has fallen from an average of around 0,10 in the 1960's and 1970's to approximately 0,06 in the late 1980's. New commercial vehicle sales have shown the same trend as that for the passenger sector.

The effect of the oil crises in the 1970's together with the depression of the world economy has had the effect of decreasing fuel use by both passenger and commercial vehicles, as shown in Fig. 5.8. In the passenger vehicle sector the annual vehicle consumption fell from 3100 litres per vehicle in 1972 to 2099 litres per vehicle in 1986, a decrease of 33%. Passenger vehicle usage has been increasing since 1986. In the commercial vehicle sector the vehicle consumption dropped by 35% over the same period but unlike gasoline has not yet recovered.

## 5.3 Future demand

It is more difficult to forecast demand in the oil sector than in the other energy sources since there is no good correlation between demand and national economics for gasoline, although there is a reasonable correlation for diesel. It is assumed that the energy intensity for oil products will follow the decreasing trend of the other energy sources. Over 80% of demand is for gasoline and diesel, and therefore the overseas trends in vehicle fuel economy will be apparent in South Africa. The changes in fuel economy in the market as a whole will however be slower than that in Europe for instance due to the high average age of passenger vehicles in South Africa.

The oil energy intensity in South Africa, expressed as total final energy per Rand of GDP, has exhibited an increasing trend, as shown in Fig. 5.9. This has been due to the increasing share of oil of the total energy market. Saturation analysis shows that the penetration into the market rose from 16% in 1950 to 33% in 1992 in spite of the pressures on oil demand caused by the oil crises in the 1970's. It is anticipated that oil has now reached its saturation level and therefore in future the intensity will appear more similar to that of the total energy market.

In line with the forecasts for the other energy sources, three scenarios have been assumed based on the different economic growth rates. It is assumed that the energy intensity will decrease at a rate proportional to economic growth. It is likely that a decrease in energy intensity will be encouraged by government by the adoption of energy conservation measures. Such measures could also include the encouragement of diesel passenger vehicles if it is likely that there will be an imbalance in the diesel/gasoline ratio in the future. Such a move to diesel vehicles is already evident in Europe and would be encouraged by any increases in world oil prices.

Figure 5.10 shows the total oil product consumption, using the various scenarios, up to 2020. Because of the effect of economic growth on the reduction in oil energy intensity, the three economic growth rates produce very similar demand figures for at least the next decade. The demand for petroleum-based products, as distinct from synthetic oil products from SASOL and MOSSGAS, has been estimated from the total demand and the capacity of the synthetic oil plants.

The contributions from the three sources is shown in Fig. 5.11 and the contribution of synthetic fuels to the market is shown in Fig. 5.12. With MOSSGAS coming onto full stream in late 1993, the 1994 contribution of synthetics will reach a high of 44% in 1994. Thereafter the contribution will decrease steadily as total demand increases. There will be a small reduction in petroleum-based fuel demand in 1994, as shown in Fig. 5.11, thereafter the growth rate will be similar to that in the 1960's.

## 5.4 Production

The various refineries are in the process of upgrading their facilities for increased throughput and to produce unleaded fuel. The capacities of each of the refineries after these changes are as given in Table 5.2.

**Table 5.2 South African refinery production capacity as at 1996**

| Refinery | Capacity ('000 barrels/day) |
|---|---|
| Sapref (Durban) | 165 |
| Genref (Durban) | 90 |
| Calref (Cape Town) | 100 |
| Natref (Sasolburg) | 95 |
| SASOL* (Secunda) | 150 |
| MOSSGAS* | 45 |
| Total | 645 |

* As crude equivalent

In terms of the forecast demand for gasoline and diesel, the refinery capacities will be able to produce sufficient diesel until the end of the first decade of next century, but there may be a gasoline shortage by the end of this century.

## 5.5 Synthetic fuels

The SASOL and MOSSGAS plants are the result of strategic considerations during the sanctions era and the projects would not have been considered viable under normal conditions. The capital expenditure has already been made and closing these plants would not have any effect on committed expenditure. Therefore any discussion on the future of these projects should consider only the operating costs. If income exceeds expenditure on operating costs, then the plant is making a contribution to capital costs.

A comprehensive report has been produced by Deloitte & Touche(36) on the economic viability of the MOSSGAS project. The conclusions of this report are that if sunk costs are excluded the project is viable though sensitive to some of the key variables. There are also positive and social benefits to South Africa, the most important being that of foreign exchange savings. There is therefore no doubt that there is no case to be made for the closing of the plant. A decision will have to be made in the future on the desirability of additional expenditure in order to increase the gas reserves for the project.

As with the case of MOSSGAS, the question surrounding SASOL is not whether it should be closed down, but what level of subsidy/protection is required for it to maintain profitability. The arguments over the applicability of the Landed Bonded Oil Price, which sets the protection level, are purely academic since an equation is required to determine the subsidy, and whether it is the present one or some other one, the result will be the same.

## 5.6 Fuel price

Recent events have highlighted the complexity of the regulated fuel price in South Africa. Much of the comment has been politically inspired and has masked the mechanism of price determination. What is possibly a more important question is whether there should be any government price control. Since the price of fuel, especially of gasoline, is an emotional issue, it is possible to lose sight of the fact that apart from a period from 1972 to 1985 the real price of gasoline has been approximately constant at about 110 cents/litre since the mid 1920's. This is illustrated in Fig. 5.13 where, after a rise to a real price (in 1990 SA cents) of 205 c/litre in 1917 (actually it rose to 220 c/litre but the graph is drawn as a 3-point moving average), it fell to between 70 and 110 c/litre over the next 40 years. The oil crises period during the 1970's had the real price rising to 243 c/litre before falling again to around 110 c/litre.

It must be remembered that a significant part of the gasoline price is government tax and the changes in this component are shown in Fig. 5.14 which expresses the government tax as a component of the total price. It has been difficult to define what the government "take" is since there are components of the price which are related to specific needs such as a road component and recently the third party insurance component. In the analysis for Fig. 5.14 only direct taxes, customs and excise, and the Central Energy Fund levy have been included.

In terms of the loading of the fuel price with indirect costs, it appears to make good sense to include in the fuel price those components which are directly related to the use of fuel such as the repair of roads, the dealing with the results of accidents on the road, etc. The cost of collecting these components is small, people are charged according to the amount of use they make of transport, and it makes it impossible to evade paying these amounts.

Interestingly the large increase in the tax component, from 5% to 37%, coincided with the reduction in fuel price in both current and real terms. In terms of pre-tax real price the cost of gasoline fell from 211 c/litre in 1918 to 79 c/litre (1990 real price) at the beginning of 1994.

The fuel price must be seen, however, in comparison with world prices. Figure 5.15, based on the prices of premium gasoline at the beginning of 1991, shows the prices from a selection of countries around the world relative to the price in South Africa and has been converted by means of ruling exchange rates. Most of the developed world and especially the countries in Europe sell gasoline at a price of between 50% and 100% higher than that in South Africa. Since the base price of gasoline, which is made up of the price of crude and the cost of refining, is similar throughout the world, the difference between the various countries is made up of the different tax rates levied on fuel. It therefore appears that by world standards the price of gasoline in South Africa is low. It is inaccurate to argue, as has been done by the Automobile Association of South Africa, that the price of fuel should be compared on the basis of the earning power of workers in the various countries, i.e. how many minutes a person works in order to be able to purchase a litre of gasoline. This argument ignores the fact that the base cost of fuel (excluding tax) is a function of the international cost of crude and of the cost of capital to build a refinery, which again is linked to international prices. The operating cost of a refinery, which could be related to local labour costs, is only a small proportion of the total cost.

The discussion on price has concentrated on the cost of gasoline, but the remarks are also pertinent to the cost of diesel fuel and other components. In the case of illuminating paraffin, the final user is usually the under-developed sector and therefore different factors govern the rate of tax.

## 5.7 Deregulation

With the end of the sanctions era it is possible to consider deregulation of the oil industry. Most of the oil industry executives have spoken out in favour of deregulation and the question is not whether deregulation should be carried out but rather how it should be carried out. Following years of regulation, the abrupt abandonment of all legislative measures would have a serious effect on the industry, and especially on its retail sector. Deregulation of the oil industry would lead to the installation of self-service stations in order to reduce cost, the closing of low-profit filling stations, and especially those in the rural areas, and the introduction of discounted fuel by groups such as supermarket chains.

The result of these actions would have the following effects:

The institution of self-service filling stations would lead to the retrenchment of large numbers of filling-station attendants. These people are relatively untrained for any other type of occupation and would have a problem in finding alternative occupation in to-day's economic climate. It would however lead to a reduction in the fuel price and a contribution to a reduction of the inflation rate. The decrease in price would be achieved by lower operating costs and would therefore have no effect on government income from tax. However there would be an effect on government expenditure because of the possible effect on social security costs.

The closing of low-profit filling-stations would result in retrenchment and an increase in the price of fuel in out-lying areas.

The discounting of fuel prices by supermarket chains would increase the number of filling stations which would be considered non-viable. The process of discounting is also bound to result in fuel being sold as a loss leader in order to attract customers to the shopping complex: the sole reason why chains would consider installing filling stations. The discounting process would inevitably lead to cross-subsidization of fuel by food products and thus an increase in the price of food. It would result in those who do not have motorcars subsidizing those who do have motorcars, i.e. the poor subsidizing the rich.

## 5.8 Unleaded gasoline

Unleaded gasoline is due to be introduced into South Africa in 1995. The original motivation for unleaded fuel was based on environmental grounds because of the toxicity of lead. The adverse effect of lead on health, in the concentrations experienced in South Africa, has been largely discounted. An economic study by the government found however that, in spite of the large cost to the refineries of providing unleaded fuel and the decrease in efficiency of throughput, the benefits to the motor industry outweighed the refinery costs. It was therefore decided that on economic grounds unleaded fuel should be introduced. This move will increase the cost of gasoline to the motorist and in view of the need to persuade people to change, unleaded fuel will need to be offered at a discount. The cost of leaded fuel will therefore have to be increased in order to recoup the cost of unleaded fuel.

The benefits of unleaded gasoline will only become evident once a decision is made to legislate for the introduction of catalytic converters which require unleaded fuel for their efficient operation. Until then there could be an increase in overall photochemical smog production depending on the way that refiners increase the octane levels of their fuel.

# CHAPTER 6. RENEWABLE ENERGY

## 6.1 Introduction

South Africa uses a significant amount of renewable energy in the form of traditional energy - fuelwood, dung, and charcoal. In comparison with other Southern African countries where traditional energy accounts for more than 80% of total final energy demand[37], South Africa's traditional energy represents an estimated 14% of final energy consumption. Over-exploitation is limiting the amount of traditional energy which can be used and the under-developed sector is changing to transitional fuels such as paraffin and LPG.

South Africa is well situated geographically for the utilization of solar energy. Whilst a small number of solar photovoltaic units have been installed, the cost of power is high, especially in comparison with grid electricity. Solar hot water systems have had a limited appeal even though it appears that they could be cost-effective in comparison with grid electricity for new private dwellings.

Wind energy has been used extensively for water pumping on farms. Even where electricity is available, wind pumps are used in fields remote from the farm homestead. Electricity generation from wind has been limited to the small farm wind generators used for charging batteries.

No tidal power has been considered for South Africa due to the very low tide range which is characteristic of open sea coasts. Some theoretical work has been carried out on the use of wave generators, but it would appear that such devices are expensive in comparison with grid electricity.

South Africa is on a stable tectonic plate and does not have the potential for geothermal generation. Such activity is possible in other areas of Sub-Equatorial Africa such as in the Rift Valley, but this potential does not extend into South Africa.

## 6.2 Traditional energy

Approximately 14% of total final energy consumption is based on traditional energy sources, the main one being wood. This is low compared with other African countries, as shown in Table 6.1, but is still high when seen against the situation in developed countries.

**Table 6.1 Traditional energy as a percentage of final energy consumption, and access to electricity[60]**

| | Traditional energy as a percent of consumption | % of population with access electricity |
|---|---|---|
| Tanzania | 96 | 13 |
| Ethiopia | 92 | 4 |
| Mozambique | 89 | 3 |
| Malawi | 87 | 2 |
| Sudan | 76 | - |
| Kenya | 72 | 5 |
| Nigeria | 68 | - |
| Ivory Coast | 66 | - |
| Angola | 60 | - |
| Zimbabwe | 38 | 16 |
| Zambia | 18 | 8 |
| South Africa | 14 | 33 |

The reliance on traditional energy is mainly in the rural areas, though Eberhard[18] estimates that approximately 38% of total energy consumption in townships is still based on wood. The breakdown in the various areas of South Africa is shown in Table 6.2.

**Table 6.2 Percentage of households using different fuels[18]**

| | Wood | Agricultural Wastes |
|---|---|---|
| Rural homeland | 99 | 80 |
| Farm labourers | 97 | 30 |
| Peri-urban | 68 | 22 |
| Townships | 38 | 2 |

Besides the use of wood and agricultural wastes, most households also use candles, paraffin, gas, etc. Eberhard[18] has estimated that the mean per capita domestic energy consumption in rural areas is as shown in Table 6.3.

**Table 6.3 Mean annual per capita domestic energy consumption in rural areas[18]**

| | | Consumption | GJ/cap | Percentage |
|---|---|---|---|---|
| Fuelwood (kg) | | 604 | 10,3 | 78,6 |
| Dung (kg) | | 118 | 1,4 | 10,7 |
| Paraffin (litres) | 23 | 0,9 | 6,9 | |
| Candles (No.) | | 27 | | |
| Coal (kg) | | 20 | 0,5 | 3,8 |
| Gas (kg) | | 0,7 | | |
| | | | 13,1 | 100,0 |

With the denudation of the "free" forests, the rural population is turning more and more to the transitional fuels such as paraffin, LPG, etc. This increases the cost of energy extensively.

The sources of fuelwood are: commercial exotic plantations, alien vegetation eradication, self-seeded exotics, woodlots, indigenous forests, and natural shrubland. By far the greatest source of wood for fuel in the rural areas is shrubland and woodlots not utilized for agriculture[18]. Natural woodland will be almost entirely eradicated by 2020 if demand remains at the present level. Eberhard estimates that a total of 500 000 hectares of additional plantation is required to meet the deficit which will be apparent by 2000. However the available land amounts to only 185 000 hectares, and therefore afforestation alone will not be able to supply the demands of the rural areas. There will be a move to transitional fuels and, in some areas, to electrification. However this will take time, and the expense of bringing electricity to some of the outlying areas will mean that they will be at the end of the priority chain. It is therefore important that a two-pronged attack is required: to afforest and manage fuel woodlots, and to introduce improved methods of using fuelwood, as in improved wood stoves.

## 6.3 Solar energy

South Africa lies within the 35°S latitude to 22°S belt and is therefore well positioned for the utilization of solar energy. The annual insolation is highest in the north-western semi-arid region where it averages 6000 Wh/m$^2$/day [39]. It declines towards the southern coast (5000 Wh/m$^2$/day) and the eastern coast (4500 Wh/m$^2$/day). Virtually the whole of the interior of the country has an average insolation in excess of 5000 Wh/m$^2$/day.

The cost of photovoltaic installations has been decreasing from a figure of over R240 per peak Watt (Wp) in 1974 to less than R11 in 1990[40]. However the cost is still high compared with grid electricity and is estimated by Kotze et al.[40] to give a cost of between 1,5 and 2,5 Rand per kWh. However, for small-scale applications (typically below 100 Wh per day) and at distances of more than 20 km from the grid, the cost is competitive with grid extension costs. There are therefore a number of niche markets for photovoltaic installations. In South Africa it was estimated[40] that by 1990 there was an installed capacity of photovoltaics of 2 MWp. Most of the installations were for telecommunications and this market is now virtually saturated. Future markets will be in rural areas for clinics, schools, water-pumping, etc. One of the largest projects in South Africa has been the provision of 300 photovoltaic-powered audio-visual systems at schools in Bophuthatswana.

There has been considerable experience in the use of photovoltaics in South Africa. Whilst the reliability of the photovoltaic panels themselves has been high, the reliability of the balance-of-system components has been less than desirable. There have also been problems with the theft of panels and components. It is also apparent that there is a lack of expertise amongst suppliers on the best combination of panels, inverters, batteries, etc.

Solar hot water systems go back some 30 years to the early pioneering work of Austin. After the 1973 oil crisis a large number of manufacturers started production but most of them have now gone out of business. It has been estimated that in most parts of South Africa some 4 square metres of solar collector are required for a middle income family. In areas such as the Western Cape where there are many cloudy days, some form of back-up is required, but even in other areas back-up would be considered necessary. A number of economic calculations have been carried out over the last twenty years and most of them have found that there is a breakeven situation in urban locations between solar heating and grid electricity, especially for new housing, since retrofitting is always more expensive. However this breakeven situation is not enough to make solar attractive for most people because of the bad reputation that the industry has received and because of the additional problems likely to be experienced such as hail damage, freezing conditions, corrosion, etc.

The possible market for solar hot water is only likely to be for domestic applications since the industrial sector has a two-part electricity tariff system which makes the cost of electricity low in comparison with the domestic consumer who pays an average price. In industry it is also possible to minimize the effect of maximum electricity demand for water heating by some form of switching when the peak demand comes on the system. If only the domestic sector is considered, then solar collectors could displace approximately a maximum of 4% of total electricity consumed.

## 6.4 Wind Energy

Wind energy in South Africa has been used extensively for water pumping for livestock on farms and in game reserves. The traditional reciprocating pump has been used with a slow speed multi-blade wind generator. A number of small high-speed wind generators have also been used for electricity generation, usually on farms for charging batteries for domestic use.

South Africa is not well positioned for wind energy generation. The inland areas generally have a low average wind speed, with only the southern coastal areas showing any reasonable wind velocity. Table 6.4 shows annual wind speed normalised to 10 m[41] and the cost of electricity generation, assuming no back-up[42].

**Table 6.4 Mean average annual wind speeds and 1992 costs of electricity generation from a 16 kW wind generator**

| | Average Wind speed (m/s) | Annual output (MWh) | Electricity cost (c/kWh) |
|---|---|---|---|
| Port Elizabeth | 4,4 | 25,5 | 54,5 |
| Alexander Bay | 4,3 | 25,1 | 55,3 |
| Cape Town | 4,3 | 24,5 | 56,7 |
| East London | 4,3 | 21,2 | 65,5 |
| Durban | 3,2 | 16,9 | 82,2 |
| Kimberley | 3,0 | 10,7 | 129.8 |
| Johannesburg | 3,0 | 8,5 | 163,4 |
| Pietersburg | 2,4 | 7,1 | 195,7 |

This should be compared with the average price per unit sold by ESKOM in 1992 of 9,16 c/kWh. The costs in the table are for a system with no back-up and the provision of back-up would add substantially thereto. Without back-up the loss-of-load probability is high and would normally be unacceptable for most applications. The use of a diesel generator gives a much lower loss-of-load probability, but the unit cost is high. It has been calculated[42] that the unit cost of a diesel generator could be decreased by having a hybrid wind/diesel system whilst maintaining the system's availability at that of the diesel unit.

The costs of electricity from a 15 kW Darrieus vertical shaft wind-generator and from 256 kW and 2 MW vertical shaft machines are greater than from the 16 kW unit selected for the calculations.

It therefore appears that the only part of South Africa where wind energy could provide a reasonable cost of energy would be on the South Cape coast. The locations selected for Table 6.4 are not the highest wind energy regions, with Cape Point and Agulhus having the highest areas where wind velocities are measured. Cape Point is a nature reserve and there would be serious objections to power generation, but it is possible that the other side of False Bay could be of equal wind strength. Cape Agulhus is also a possible site for wind generation. Work carried out by Denison[43] has shown that natural wind funneling in certain positions near Cape Agulhus could increase the wind energy available, above that at the measurement site at the lighthouse, by almost 100%. The average annual wind speed at the optimum site was calculated to be 11,4 m/s. This would bring the cost of electricity to around 20 c/kWh or approximately double that of grid electricity. This is however still without any stand-by power to make energy firm. It does appear however that wind energy could be competitive with other forms of renewable energy such as photovoltaics.

### 6.5 Ocean energy

The South African coastline faces into the open ocean and therefore there is no scope for tide range enhancement due to natural funneling in estuaries, etc. Tide ranges are typically 1,5 metres which should be compared with the 8 metres of the English Channel and the 12,4 metres of Cobequid in Canada. There is therefore no significant tide energy potential in South Africa.

The concept of an ocean thermal difference system uses the difference in temperature between the hot surface and cold bottom waters. This is a concept which has been considered for tropical regions. Off the Natal north coast temperatures range from 26°C at the surface to 11°C at a depth of 500 m. This temperature is less than the workable required range of 30° to 3°C. The position off the Natal northern coast is also far from any significant energy load centre.

One concept which has not been adequately researched is the use of sea currents. The Agulhus current exhibits average surface velocities of 1 to 2 m/s with extremes of 3 m/s. Work is being carried out on the potential off the Florida coast where velocities are 1,95 m/s at a depth of 20 metres. However the location of the potential source of current energy is likely to make it expensive when delivered to a load point.

Wave energy has been considered in the past and work has been carried out by Nurick(44) at the University of Cape Town and by Retief et al.(45) at the University of Stellenbosch. The highest potential for wave energy off-shore is off the Western Cape with a potential of 14 kW/m of wave front at Slangkop, 30 km from the coast and in a water depth of 200 m. Retief proposed an on-shore arrangement which would amplify wave height by channeling waves into a "Wave Energy Converter".

Costs of providing energy from ocean sources are high and it has been estimated that in the UK where wave energy can reach 70 kW/m the cost is likely to be double that of grid electricity. In South Africa this would mean a wave energy to grid electricity price ratio of between 4 and 5. The economic study of Nurick, when escalated to 1992 prices, gives a cost of between 68 and 194 c/kWh. This is between 15 and 40 times grid electricity cost (and without grid reliability). The cost of the Retief system was reported as being more favourable, but the system was abandoned due to lack of funding.

Whilst not enough research has been carried out on ocean energy in South Africa, it does not appear promising in comparison with the large-scale and inexpensive coal energy and with other sources such as imported hydro-power.

### 6.6 Hydro-power

South Africa is a relatively dry country with periodic droughts and therefore does not have a large hydro potential. However 540 MW of hydro-power has been developed on the Orange River by ESKOM, which contributed 0,5% of ESKOM's electricity sales in 1992. In addition, the Cahora Bassa scheme in Mozambique, when it is brought back into service, will provide a further 1920 MW of capacity, and there were imports from the Ruacana power station in Namibia of 121 MW in 1992. In South Africa there is future potential of hydro-generation from the Tugela River in Natal. Further into the future there is a possibility of importing power from Namibia, Angola, Zaire, and from the Zambezi Valley.

There is also the possibility in South Africa for small-scale hydro capacity. At present there are some 62 MW of hydro-generation in the Transkei, with two 3 MW sets at First Falls, two 5,5 MW sets at Second Falls, two 0,4 MW and one 1,6 MW sets at Ncora and three 14 MW sets at Collywobbles on the Mbashe River[40]. There are also some smaller farm-scale machines mainly in the Eastern Cape.

No detailed studies have been carried out on the potential for small-scale hydro in South Africa. It is very site-specific and therefore little generalization is possible. However it is likely that in certain locations, remote from the grid, micro-hydro plant could be competitive with other forms of energy, especially in under-developed rural areas in a 400 km wide band stretching north-east from East London into Natal[40].

## 6.7 Bio-fuels

The term bio-fuels includes those fuels derived from vegetable matter and also alcohol fuels and vegetable oils. Bio-gas is included under a separate heading.

Significant work has been carried out in South Africa on the production and utilization of bio-fuels (see for example ref. [46]). The main contender is ethanol to be used primarily as a transport fuel. It can be used as a blend fuel as originally used in Brazil and now being used in Zimbabwe and Malawi. It is of interest that a blend of 50% ethanol and 50% gasoline was available from about 1947, until fairly recently, as Union Spirit, mainly on the Natal coast, which motorists would dilute further themselves. Additional work was carried out on the use of ethanol during the 1970's at the Universities of Cape Town and Natal in passenger vehicles and in tractors. In addition more work was carried out on the use of methanol. Methanol is normally obtained from gas or coal but can also be obtained by the destructive distillation of wood. The use of methanol is in many ways similar to that of ethanol. The source of ethanol is sugar cane and maize.

The price of ethanol production depends on a number of factors and has not been adequately published. However in Brazil it is accepted that ethanol has to be subsidized at the filling station and the subsidy is used as a foreign exchange limiter and is therefore justified by the government.

In South Africa ethanol is already blended with gasoline, using synthetically derived ethanol from the SASOL process. The areas of supply is the Highveld region. Thus a large part of the available market for blend fuels is already supplied, though this position could change in the future if overseas markets for ethanol could be found. In addition, MOSSGAS will be producing ethanol and this could also find its way into the coastal gasoline. Thus there is only a limited market for any blend ethanol.

Work has also been carried out by the Department of Agriculture on the use of vegetable oils for use in diesel engines[47]. The main work was carried out on sunflower oil. The results were very encouraging, but the work was stopped since the main objective was to prove that such use was feasible. No adverse effects are expected with the use of sunflower or most other vegetable oils if they are treated satisfactorily. However, the use as a fuel is in competition with the oil as a food product and is therefore expensive. The present cost of vegetable oil at a supermarket is of the order of 500 c/litre. Whilst the use of bulk fuel would give a price significantly less than this, the price is in competition with diesel fuel at a pre-tax cost of around 100 c/litre.

It is therefore apparent that alcohol fuels and vegetable oils are not competitive with petroleum-derived gasoline and diesel fuel. However the technology does exist for their implementation if the economics change or if there is concern with fuels security.

## 6.8 Bio-gas

The term bio-gas is to describe gas generated from agricultural wastes such as crop residues, bagasse, and wood residues, from animal waste such as the generation of methane from dung, and from the generation of gas from municipal wastes.

Work has been carried out in South Africa on the generation of gas from wood waste and from vegetable and animal wastes by the microbial decomposition of organic matter. Small plants have been built and operated at various locations. The costs are very site- and source-specific and no generalization on cost is possible. It is seen that gas production can be a useful method of waste disposal where this is a problem[61].

Pioneering work was carried out in South Africa on the production of gas from animal manure, but little has been done in the recent past. The application of this method of digestion requires an intensive animal concentration as, for instance, in dairy herds which are kept mainly indoors. The use of bio-digesters also requires an adequate supply of water. This method has less application in South Africa than in other countries, but some digesters have been built.

The use of municipal landfills for the production of methane for power generation or for heating has been researched. Schemes have been implemented at the municipal landfill site in Grahamstown and at the AECI site in Modderfontein, Johannesburg. Mearns and Dancig[48] analysed the refuse disposal of 33 municipalities and found that in 1990 the refuse disposed of in landfills could have generated 3120 GWh or 2% of ESKOM's generation in that year. However many of these sites are too small or too far from a load source to warrant consideration. Nonetheless it is technically possible for Reef waste disposal sites to generate some 25% of Johannesburg's electricity consumption.

A number of municipalities are currently investigating the use of gas from landfill. It must be borne in mind however that the generation of this gas is not as efficient a method of obtaining energy as is the practice of combusting municipal refuse. Such combustors have been operated in many parts of the world, but it is recognised that special consideration must be given to the neutralization of acid gases given off, mainly, from the combustion of plastics, and for the elimination of any dioxins produced.

## 6.9 Conclusion

There are a number of renewable energy sources currently being used, the most important being fuelwood. All the renewable energy forms, except for wood, are more expensive than grid electricity and therefore are not in competition with electricity based on coal, hydro or nuclear. However at remote sites the renewable forms are cost-effective with alternates such as diesel power. The economics of each renewable energy form is a function of location, size of load, and other factors such as the need for a maintenance-free source. Thus most of the renewable energy forms, with the possible exception of ocean energy, have a niche market. Most of the attention is being given to photovoltaic generation and potential cost decreases are likely to increase its share of the total market. Possibly not enough attention has been given to wind energy, especially in the southern part of the country.

The total contribution to final energy demand by renewable energy, with the exception of fuelwood, is likely to remain low. The problem of the shortage of fuelwood is likely to increase and in spite of moves to provide grid electricity to as many people as possible, attention will have to be given to the development of a policy on re-afforestation for energy purposes.

# CHAPTER 7. ENVIRONMENTAL FACTORS

## 7.1 Introduction

South Africa generates and consumes some 75% of the energy of the sub-equatorial region of Africa and in the process emits the highest amount of pollutants. The pollution problem is compounded by the high density of electrical generating plant in the Eastern Transvaal and by the particular meteorological conditions in parts of the country. Most of the electricity generation is from coal and at present there is no legislative requirement for flue gas clean-up.

There is also no "clean-air" legislation in the sub-economic residential areas in which coal is predominantly used, resulting in high levels of sulphur-dioxide and smoke which make conditions critical in these areas, especially in winter. There are however "smoke-free" zones in certain cities.

Transport air pollution is similar to that in other countries, with the worst areas being central city areas. Photochemical smog is one of the pollution forms giving rise to concern. Lead has not yet become a major issue, but lead-free gasoline is to be introduced by 1995.

The problems associated with the environment are closely linked in South Africa to affordability. South Africa is a developing country in terms of its Gross Domestic Product per capita and is presently going through a major political change in which wealth redistribution and the upliftment of the under-privileged sectors of the community are high on the political agenda. Economic growth and the resultant job creation opportunities are therefore vital components of a stable future for the country. Any measure to be introduced to combat pollution must therefore be looked at in the context of competition for scarce funding and for skilled manpower.

Coal produces some 77% of total primary energy in South Africa, petroleum and oil-from-coal produces 13%, fuelwood produces 7%, nuclear 2% and hydro 1%. Consideration of the environmental effects of these energy sources must take into account not only the total amounts of primary energy used and the pollutants evolved in the process, but also the geographical locality and the method of emitting the pollutants. Thus use of coal in a power station cannot be compared directly with the use of coal in a domestic fireplace since it is their concentrations and effects on humans, animals, vegetable matter and materials that is important.

## 7.2 Coal

Coal is used mainly for electricity power generation and for synfuels production, as shown in Table 7.1.

**Table 7.1 Sectorial breakdown of coal consumption 1989[52]**

| Sector | Mt | Percentage |
|---|---|---|
| Electricity | 73,3 | 57,0 |
| Synfuels | 35,2 | 27,4 |
| Industry | 5,6 | 4,3 |
| Metallurgical | 8,0 | 6,2 |
| Domestic | 6,2 | 4,8 |
| Transport | 0,2 | 0,1 |
| Mining | 0,3 | 0,2 |
| Total | 128,8 | 100,0 |

The combustion of coal produces various pollutants, the main ones being sulphur dioxide ($SO_2$), oxides of nitrogen ($NO_x$), carbon dioxide ($CO_2$), carbon monoxide (CO), particulate matter, and hydrocarbons ($HC_x$). Gerson[52] has evaluated the quantities of each of these pollutants involved from each sector as shown below.

**Table 7.2 Sectorial pollutant emissions due to coal combustion (1989)**

| Sector | $SO_2$ (kt) | $NO_x$ (kt) | $CO_2$ (Mt) | Part. (kt) | $HC_x$ (kt) | CO (kt) |
|---|---|---|---|---|---|---|
| Electricity | 1393 | 660 | 148 | 44 | 11 | 37 |
| Synfuels | 3 | 6 | 36 | 1 | 246 | 0 |
| Industry | 179 | 51 | 21 | 281 | 9 | 28 |
| Metallurgical | 151 | 60 | 17 | 310 | 4 | 8 |
| Domestic | 31 | 2 | 4 | 16 | 16 | 74 |
| Transport | 3 | 0 | 352 | 2 | 2 | 7 |
| Mining | 6 | 2 | 1 | 11 | 0 | 0 |
| Total | 1766 | 781 | 227 | 665 | 288 | 154 |

Whilst these values show the sectorial contribution to pollution, they do not indicate their contribution to concentrations and to their effect on the environment.

7.2.1 Coal for electricity generation:

Most of the power plant in South Africa is concentrated in the Eastern Transvaal, with some 22 000 MW of capacity. Emissions are through tall stacks and the power plant is fitted with electrostatic precipitators which are designed with efficiencies of over 99,8%. No power plant is fitted with sulphur dioxide scrubbers since it is considered that South African coals have a very low sulphur content, typically less than 1% compared with European coals with typically 1 to 2% for most coals internationally and with 3 to 5% for some USA coals.

Tyson et al. [50] has compared the sulphur dioxide emissions from power plant in the Eastern Transvaal with that from plant in other parts of the world. Table 7.3 shows Tyson's comparison.

**Table 7.3 Sulphur dioxide emissions from power stations**

| Region | $SO_2$ kt | Area ($km^2$ 000's) | $SO_2$ ($t/km^2$) |
|---|---|---|---|
| USA average | 15816 | 9362 | 1,7 |
| Ohio | 2120 | 106 | 19,9 |
| Texas | 356 | 692 | 0,5 |
| Pennsylvania | 1037 | 1465 | 7,1 |
| Eastern Canada | 726 | 3798 | 0,2 |
| West Germany | 1800 | 247 | 14,3 |
| East Germany | 3245 | 108 | 30,0 |
| United Kingdom | 3500 | 244 | 14,3 |
| South Africa | 1191 | 1123 | 4,3 |
| Eastern Tvl | 937 | 30 | 31,3 |

These figures have been used to demonstrate that the Eastern Transvaal is more highly polluted than the infamous East Germany and that it has a higher emission level than the Ruhr area of Germany.

Figures like these have to be treated with care since what is important, in terms of the pollution in the region, is the effect of emissions on ground level concentrations. In the other parts of the world which are highly industrialized, such as East and West Germany, in addition to power plant there is a high concentration of other industrial plant which together with the power plant produce the unacceptably high concentrations. What is important therefore is the ground level concentration and the contribution of each of the other sources to that concentration. In the Eastern Transvaal there is also some industrial activity and in certain areas there is a high level of pollution from the use of coal for domestic purposes. In addition, there are such sources as burning discard coal dumps which contribute sulphur dioxide at very low heights of emission, and the burning of veld during the winter months.

Lennon and Turner[49] have compared $SO_2$ ground level concentrations in the Eastern Transvaal with those in other parts of the world and show that the Eastern Transvaal annual average concentrations are approximately the same as those in rural areas of the UK and some 66% of those of the average of cities in the UK. The Eastern Transvaal annual concentration is also 40% of that in Soweto and 33% of the maximum permissible level. Whilst the annual average concentrations are less than 50% of the maximum USA Environmental Protection Agency annual levels, the daily and hourly levels are exceeded on occasions. Gerson has prepared an exceedence table, reproduced here as Table 7.4.

**Table 7.4 Exceedence of Department of Health guidelines for ambient $SO_2$ concentrations in the Eastern Transvaal Highveld[52]**

| Year | Number of exceedences | |
|---|---|---|
| | Hourly | Daily |
| 1979/80 | 4 | 0 |
| 1980/81 | 10 | 5 |
| 1981/82 | 3 | 0 |
| 1982/83 | 2 | 1 |
| 1984 | 2 | 1 |
| 1985 | 1 | 0 |
| 1986 | 16 | 1 |

Of the large number of hourly exceedences in 1986, 15 were adjacent to one power station. In 1980/81 there were a large number of exceedences at a point near to a burning coal-dump.

The concentrations of $NO_x$ in the Eastern Transvaal are well below permissible levels, as shown in Table 7.5.

**Table 7.5 $NO_x$ concentrations in the Eastern Transvaal Highveld, 1983-1988**

| Region | Maximum levels during period | | |
|---|---|---|---|
| | Hourly | Daily | Annual |
| Komati | 262 | 115 | 22 |
| Elands | 263 | 65 | 14 |
| Phoenix | 321 | 91 | 19 |
| DoH Guideline | 1080 | 540 | 270 |

Particulate matter in the Eastern Transvaal has been measured by ESKOM, and Lennon and Turner[49] quote the annual concentration of fine particulate matter at 18 micrograms per cubic metre. The Department of Health Guideline for suspended solids is 100 micrograms.

Besides the effect of emissions on the levels of $SO_2$ and $NO_x$ and particulates, there is also concern regarding acid rain deposition down-wind of the power stations. Measurements have been made of the acidity of rain in a number of areas as far as the Kruger Park, the Orange Free State, and the Drakensberg. pH levels of between 3,9 and 4,8 are reported, with the highest pH levels (lowest acidity) at Cathedral Peak in the Drakensberg and Punda Maria in the Kruger Park. Lennon and Turner[49] point out that it is not the pH level itself which is important but the material deposition. They give values of 2 micrograms per cubic metre for sulphate deposition in the Eastern Transvaal compared with 5 in the central United Kingdom, 4 in the north-east of the USA, and 5 in northern Europe. Similarly, nitrates are 1 microgram per cubic metre for the Eastern Transvaal, compared with 2,5 for central UK, 3 for north-east USA, and 2 for northern Europe.

Turner[55] has shown that there has been a downward trend in acidity over a seven-year period. He estimates that near the Eastern Transvaal Highveld area some 50% of the acidity contribution is due to combustion of fossil fuels, whilst at more remote areas, e.g. Louis Trichardt, up to 50% is due to combustion of biomass from the burning of grasslands and forests.

It thus appears that the situation in the Eastern Transvaal has not reached a critical situation, nor is it as bad as has been made out in the popular press. However there is concern that without adequate planning the situation could worsen. At present there is an embargo on the positioning of power stations in a specified area of the Eastern Transvaal. In view of the large cost of the introduction of anti-pollution measures on power stations, a detailed study is required of the impact of further power stations on $SO_2$ concentrations, the contribution of power plant and other sources to the concentrations, and on the relationship between power plant siting and concentrations in the future.

7.2.2 Coal for urban use:

Coal in the urban environment is used for domestic and commercial purposes. Historically $SO_2$ was the first pollutant which was implicated in health effects. Control has been executed world-wide on $SO_2$ emission and South Africa has followed the various guidelines. In South African cities the concentration of $SO_2$ has been generally declining at a rate of 1,5% per annum over the last two decades. Whilst this is true of the central city and suburban regions, it is not true for black townships and informal settlements, especially on the Transvaal Highveld.

The cheapest source of energy for cooking and heating is coal and it is largely used in stoves with low heights of emission. During winter inversion conditions, the levels of $SO_2$ and particulate matter are well above the permissible levels. de Kock et al.[53] quote hourly means of respirable dust exceeding 900 micrograms per cubic metre in Soweto, and daily averages of 200 micrograms per cubic metre compared with Department of Health guidelines of 300 micrograms per cubic metre.

Terblanche et al.[54] have measured the levels of dust to which individual children are exposed during a typical period and found that children living in homes using only coal were exposed to dust concentrations almost double that of children living in houses using electricity. The report concludes that the health risk of children living in houses using coal as the predominant form of energy are exposed to unacceptably high particulate levels. Gerson gives values measured in Soweto in 1982 of 4520 micrograms per cubic metre as an hourly value and 1040 micrograms per cubic metre as a daily maximum. He summarized the $NO_2$ measurements in Soweto over a one-year period in 1983/84. The results and a comparison with guideline values are given in Table 7.6.

**Table 7.6 $NO_x$ maximum concentrations in Soweto (micrograms per cubic metre)**

| Averaging | Actual | Guideline period |
|---|---|---|
| Instantaneous | 890 | 1890 |
| Hourly | 494 | 1080 |
| Daily | 147 | 540 |
| Monthly | 72 | 405 |

No detailed measurements of $SO_2$ are available, but it is expected that the levels would be commensurate with those of particulate matter.

It is obvious therefore that one of the most serious health hazards associated with energy utilization is due to the use of coal for domestic use in low-income dwellings, especially on the Highveld.

## 7.3 Liquid fuels

Liquid fuels consist of gasoline and diesel fuel produced both from petroleum and synthetically from coal and from natural gas. Because of its prevalence within the central city area and nearby densely populated areas, the internal combustion engine is potentially one of the most serious sources of pollution. Vehicles produce various pollutants such as hydrocarbons ($HC_x$), carbon monoxide (CO), oxides of nitrogen ($NO_x$), carbon dioxide ($CO_2$), volatile organic compounds (VOC), aldehydes, lead, and particulate matter.

### 7.3.1 International situation:

In developed countries the problem of the internal combustion engine emissions has been recognised over the last two decades and various legislation has been enacted in order to limit the pollution problems. The leader in this field was the USA where conditions in California prompted regulations on emissions. The USA enacted its Clean Air Act in 1968. Reductions in emissions were legislated in phases up to 1979 and resulted in a reduction of emissions for new cars by 90% over this period. Further reductions will be required by 2004. The USA limits with time are shown in Table 7.7.

**Table 7.7 USA legislation on emissions from new passenger vehicles (grams per mile)**

| Model year | HC | CO | $NO_x$ | Partic. |
|---|---|---|---|---|
| Pre-1970 | 15,0 | 90,0 | 6,2 | - |
| 1970 | 4,1 | 34,0 | - | - |
| 1972 | 3,0 | 28,0 | - | - |
| 1973 | 3,0 | 28,0 | 3,1 | - |
| 1975 | 1,5 | 15,0 | 3,1 | - |
| 1977 | 1,5 | 15,0 | 2,0 | - |
| 1980 | 0,4 | 7,0 | 2,0 | - |
| 1981 | 0,41 | 3,4 | 1,0 | - |
| 1982 | 0,41 | 3,4 | 1,0 | 0,6 |
| 1982 | 0,41 | 3,4 | 1,0 | 0,2 |
| 1994 | 0,25 | 3,4 | 0,4 | 0,08 |
| 2004 | 0,125 | 1,7 | 0,2 | 0,08 |

The limits set by the US government soon resulted in a situation where the standard could be achieved only by the use of catalytic converters. In order to install catalytic converters lead has to be removed from gasoline since it poisons the catalyst. Increasingly stricter limits have been instigated and motorcar designers have produced technological solutions to the problem, including improvements in the efficiency of catalytic converters. At one time it was considered, in California, that the only way to improve conditions further was by the use of alternate fuels such as methanol and ethanol. The oil companies responded by developing improved fuel formulations, such as the "reformulated gasoline" and "reformulated diesel" which are claimed to achieve the same benefits as the alcohol fuels.

Further moves in California have resulted in the requirement for 2% of zero-emission vehicles by the end of the century and 5% by 2005. Zero-emission vehicles are considered to be only electric vehicles at this stage, though fuel cells and hydrogen are also being considered.

The rest of the world is following the USA lead, with most developed countries introducing unleaded fuel to enable the fitting of catalytic converters. Whilst catalytic converters are not mandatory, they are seen as the only way of meeting the emission standards, though the designers of "lean-burn" engines see this as an alternative route to meeting regulations. However the latest European, Japanese and US standards can be met only by the use of 3-way catalyst systems.

Table 7.8 shows the countries that have introduced emission legislation or are developing standards.

**Table 7.8 Countries that have introduced legislation on limits to motor vehicle emissions**

**Introduced legislation**

Australia
Brazil
Canada
Europe
Hong Kong
Japan
Mexico
Singapore
South Korea
Taiwan

**Developing standards**

China
India

The USA was again the first country to introduce legislation on diesel engine emissions, with regulations being implemented from 1970. The European Community has followed and emissions of CO have been reduced from 14 g/kWh to 4,5 g/kWh or a reduction of 68%. Hydrocarbon emissions have been reduced by 68% and oxides of nitrogen by 56%.

7.3.2 The South African situation:

South Africa does not have any legislation concerning road vehicle emissions other than a "black smoke" legislation for heavy diesel vehicles. Because of a shortage of inspectors, even this legislation is not being applied. However, South Africa imports vehicle technology from Europe and from Japan and it is therefore likely that there have recently been decreasing exhaust emission levels because of improving technology. Further exhaust emission reductions are not expected in South African cars until the availability of unleaded gasoline will allow the use of catalytic converters.

The density of motor vehicles in South Africa is less than that in developed countries and therefore one can assume that the air pollution levels are less. However there is a growing vehicle population and, due to meteorological or topographical conditions, pollution concentrations may already be bad in certain places. It is known that Cape Town experiences episodes of photochemical smog under conditions of strong thermal inversions which occur during spring and autumn.

Concern has been expressed with the levels of lead in South African gasoline which is higher than that of most of the developed countries. This difference has been highlighted by environmental groups and led eventually to a government requirement that unleaded fuel be made available in South Africa from 1995. It has been shown however[56] that under South African conditions lead cannot be considered a health risk and therefore a move to unleaded fuel cannot be made on health grounds. The decision was made however on the grounds that the benefit to the motor manufacturers would outweigh the additional cost to the refiners of making unleaded fuel. The benefit was due to the manufacturers being able to continue using overseas-sourced technology and the possibility of exports to other parts of the world. However the introduction of unleaded fuel could lead to an increase in photochemical smog unless care is taken with the formulation of the unleaded fuel. Thus the introduction of unleaded gasoline is not expected to have any beneficial effect on the environment and could well have a detrimental effect. The only environmental benefit is that it will allow the introduction of catalytic converters on vehicles, as mentioned above.

7.3.3 Used oil:

Lubricating oil is released from the operation of internal combustion engines in one of four ways:

Leakage from the engine and deposition on the road.

Combustion of oil due to leakage around the piston rings and its subsequent release to the atmosphere with the emissions from the vehicle.

Combustion in two-stroke engines where oil is added directly to the fuel.

Disposal of used oil mainly through discards into the ground and thence through to ground water.

During the sanctions era conservation of petroleum products was considered an important objective and a re-refining industry was developed due to the provision of a subsidy on all lubricating oil recycled. There is no longer such an incentive on strategic considerations and without a subsidy new imported oil is cheaper than the re-refined oil. Most of the oil obtained from motor vehicles is therefore dumped, often by do-it-yourself motorcar users. This has become a serious disposal problem, with dumping being carried out into municipal drains or into the open veld.

## 7.4 Global warming

There is a world-wide concern with the emission of certain gases which could increase the temperature of the earth. These gases include carbon dioxide, methane, $NO_2$, and others. On a global scale carbon dioxide contributes around 56% of man-made gases in terms of the global warming potential, CFC's contribute 24%, methane contributes 15%, and the rest is from minor gases(56).

The evidence for global warming is still not conclusive and it cannot be determined at this time whether the current increase in world average temperatures is due to man's effect or whether it is one of a series of shifts in temperature which are known to have occurred in the past. However, in view of the potentially catastrophic effects, the world has decided to adopt a precautionary attitude, adopting a policy to minimize the emissions of these gases.

In view of the cost associated with any significant reduction of greenhouse gases, especially in the power industry, care has to be exercised in making decisions. Whilst the developed world is adopting a policy of "precautionary action", the developing world is adopting a "no regrets" policy. This latter policy suggests(56) that organisations should act now on the basis of current knowledge and take that action which might be warranted because of other reasons. Where two options have equal merit, for instance in terms of economics, the one that is the most "greenhouse friendly" should be adopted. Under this policy it is considered that the current scientific uncertainties are still too large to warrant costly preventative action which could damage the national economy.

At the moment emissions of carbon dioxide, for example, by the developing countries amount to 19,3% of global emissions(56). South Africa contributes approximately 1,5% of the world's emissions, of which half, or 0,75%, come from the power industry. In view of the above it is important to ensure that South Africa's contribution to a reduction of global warming is commensurate with its emissions, and that any measures taken should not unduly interfere with the need to develop the economy of the country.

Lennon[56] recommends that South Africa's stand on the issue of global warming should be to reduce its energy demand and to introduce improved efficiency both in energy production and in energy consumption. Some of his recommendations include:

**Short term**

Improved plant efficiency
Demand-side management
Electrification
Research into alternative energy options

**Medium term**

Advanced boiler concepts
Use of integrated cycles
Alternative energy sources for stand-alone applications
Development of improved systems such as fuel cells
Nuclear and hydro power

**Long term**

Nuclear fusion
Solar power
Advanced alternative generation

## 7.5 Nuclear power

South Africa has two reactors at Koeberg producing electricity for the national grid. At the time that the decision was made on nuclear power, the relative cost of nuclear power on the western coast was less than that of coal-based electricity together with the transmission lines necessary to bring the power to the Western Cape. There were also technical advantages in having a generating source at the end of a long transmission system between the Highveld and the southern parts of the country. There was also an advantage from the point of view of electrical security since a break in the north-south transmission system would not leave the southern part of the country completely without power.

Since the decision was made to go nuclear the economics have changed and at present it is not economic to build a second power station. The situation is therefore that the present plant has to be operated safely and the nuclear material disposed of in an acceptable fashion. With one nuclear power plant the spent fuel can be kept on site for an indefinite time and no reprocessing or external burial need be considered. The low-level radioactive material is being disposed off at Vaalputs, some 300 km from the power station. The geology of the area is considered stable and the rainfall is very low, and if there was a leak it would travel only very slowly through the ground. There should therefore not be any cause for concern for storage under the present conditions.

The safety of the Koeberg power plant and of all installations handling nuclear grade material and waste from such activities is under the control of the Council for Nuclear Safety. This body is staffed with competent technical staff who are trained in the field of nuclear risk assessment. The Council, and its Board, are under the jurisdiction of the Department of Mineral and Energy Affairs. The Board consists mainly of members of various government departments and they are appointed by the Minister. The impartiality of this organization could therefore be questioned since the interests of the Department of Mineral and Energy Affairs could take precedence over public safety.

Whilst additions to the present nuclear capacity are unlikely in the medium term, it has to be recognised that in the long term nuclear power is likely to provide an increasing amount of the world's energy supply. Therefore a watching brief needs to be kept on developments in this area and steps must be taken now to ensure adequate provision for sites, etc. in the future.

## 7.6 Social costs of energy usage

The cost of energy production and utilization is normally considered as the cost to the supplier and includes the capital and operating costs of the producer and distributor. However the true cost of energy utilization to the country includes not only these direct costs, which are internal to the producer and distributor, but also the costs which devolve onto society and are thus external to energy supply. These "externality" costs include the effect of energy on the environment and include human health aspects, both to the producer and user, but also to the public at large, the effect on the animal health, on flora, and on materials. Thus adverse health effects of breathing a polluted atmosphere are translated into the cost of providing medical assistance by the state, the cost of a decrease in life span, etc. The cost on materials is made up of an increase in corrosion of metals, the cost of cleaning masonry, etc.

It is necessary to quantify these externality costs in order to determine the true cost of each energy production method to the country. Some of the externality costs are difficult to determine because of insufficient information, or due to the intangible nature of the cost, i.e. it is difficult to put a cost onto the aesthetic consideration of a smoking chimney.

Some preliminary work(58) has been carried out on the relative externality costs of generating electricity by coal, nuclear, solar and wind energy. This work included health aspects not only due to the generation of electricity and the effluent from the power plant, but also included the effects up-stream of the power plant, i.e. the effects due to the mining of coal, the mining of iron ore, and its processing into steel for the construction of the power plant, etc. The analysis showed that coal-fired power plant had the highest externality cost, followed by nuclear, solar and wind in that order. The relevant externality costs are shown in Table 7.9.

**Table 7.9 Externality costs of the production of electricity by coal, nuclear, solar and wind methods (1992)**

| **Method** | **External cost c/kWh** |
|---|---|
| Coal | 0,64 |
| Nuclear | 0,180 - 0,547 |
| Solar | 0,007 - 0,037 |
| Wind | 0,004 - 0,025 |

These costs do not include all the costs which need to be considered because of the lack of information under South African conditions. They show however that the external costs are small compared with the production prices of electricity and would not affect the relative merits of each of the electricity generating methods. The external cost of coal-based electricity is 15% of the production cost, the cost of nuclear is between 2% and 5% of production cost. The percentage cost of solar and wind are much less, but this is due to the high cost of these forms of energy at present. However it could be argued that such costs should be included into the price (internalized) of each form of energy in order to recover, for the state, the cost to it of energy usage.

## 7.7 Economic considerations

One of the difficult aspects of environmental policy formulation is the problem of maintaining a balance between the costs of implementing policy measures and the return from them on a national basis. In a country such as South Africa, where economic growth is required to allow for the development of the under-privileged sector of the community, it would be easy to postpone expenditure on environmental matters. However it must be realised that there is a close dependency between the environment and economic growth. The President's Council(59)recognizes that without a sound environmental policy as a base, the planning of the workings of the economic system risks the depletion and depreciation of the natural environment's function. An economy can survive for some time without concern with the environment, but sooner or later it will result in damage to the economy.

What is required is adequate knowledge to be able to make the decision on the correct action to attain a sustainable situation. The environmental problems facing the old "iron curtain" demonstrates what can happen if environmental factors are ignored. Equally it must be realised that the South African economy, especially at this time, cannot afford the environmental policy niceties which are considered in developed countries, and especially by Germany and the Nordic countries.

## 7.8 Conclusion

The most serious pollution aspects arising out of energy generation and use are:

Pollution implications from electricity generation, especially in the Eastern Transvaal. The situation there has not reached crisis point, in spite of the reports in the popular press, but a medium- and long-term policy is required as soon as possible to allow for planning for power plant and industrial development in the region. More measurements need to be taken in the region and an independent body should be set up to monitor the research work being carried out by ESKOM and other bodies.

Coal combustion in the domestic situation. There is a critical situation in townships on the Highveld where coal is used as a cheap source of heating and cooking.

Whilst electrification is seen as the solution to the problem, it is evident that this is not a short-term answer, and further work needs to be carried out on alternate forms of energy and the use of smoke-free stoves to alleviate the problem in the short term.

Emissions from motor vehicles. A decision has been taken on the introduction of unleaded fuel, but this is unlikely to lead to any improvement in the short term and could well result in an increase in photochemical smog. An urgent in-depth study is required of the medium- and long-term effects of adopting a number of policy measures which would include legislation in line with overseas practice. In view of the large financial burden to the country of an incorrect policy decision, the investigation must be thorough and must precede any policy decisions.

The disposal of used lubricating oil from vehicles has become an invisible but environmentally threatening problem and a policy is required from government on the best environmentally acceptable manner for its disposal.

The nuclear option. In view of the long-term potential for nuclear power, it is important to analyse its environmental effects and to arrange for the implementation of, for instance, a pro-active site purchase policy to ensure that nuclear power is allowed to operate in the most environmentally acceptable manner.

# CHAPTER 8. POLICY CONSIDERATIONS

## 8.1 Policy considerations

This report is written as an aide-memoire for policy formulation. Policy formulation itself is a function of management. In energy there are policy matters affecting the operation of individual power plant, policy matters affecting each energy industry, and policy matters affecting the country. Each policy has to operate within the framework set by the level above it, a power plant has to operate within the terms set by the utility, and government policy will affect the planning of a utility. In order to function efficiently, the policy formulated must be consistent through time, must be formulated considering all the factors affecting the environment in which the enterprise operates, and must allow the person "at the coal-face" to have input into policy affecting his operation, and to control his operation subject only to the wider implications of policy.

It is important to understand that each level of the energy system has to operate in such a way that it minimizes costs to itself. It is therefore not incumbent on, for instance, an electricity utility to adopt a level of environmental control which would increase its cost. Environmental levels or standards must be set by the State and the utility must be allowed to achieve these standards in the most cost-effective manner to itself. This is also true of the use of energy for social purposes. It is the role of government to provide for the social well-being of all its people. If this involves the provision of energy below cost, it should arrange this by, for example, subsidies to a particular class of consumer. It should not be the role of the utility to act as a social agent for government.

With the changes taking place in South Africa there will be a tendency to start afresh with a clean slate and to change things for the sake of change. There is a saying in engineering however which goes "If it ain't broke, don't fix it". Africa is full of examples of what can go wrong if government tries to interfere in the internal operation of the energy industry.

It is important therefore to look at the energy scene in South Africa at this time, to determine what "ain't broke" and to put each energy sector into the wider national need, and in fact in the international context. The previous chapters have tried to summarize the energy position in each sector and to attempt a forecast of future energy demand and supply against a series of economic "scenarios". This chapter summarizes those factors which it is considered need policy decisions, and the work required to be carried out in order for such policy decisions to be made.

The basic premise for energy policy formulation is the economic well-being of all the persons of South Africa. This involves the analysis of the energy demand of the individual as well as the demand of organizations and industries. It is accepted that the prime requirement of the country is economic growth. South Africa is fortunate that it has large natural resources which have allowed economic development in the past. Inexpensive energy, by world standards, has assisted this exploitation of resources. In the future a move will have to be made from economic reliance on primary commodities to increasing reliance on manufactured goods. However, inexpensive energy will remain a requirement for competition by local industry on the world market. It is therefore important to minimize energy cost to industry and allow it a competitive edge.

The policy implications which it is considered will require action at the government level are discussed below.

## 8.2 Electricity

South Africa is one of the cheapest producers of electricity in the world. This cheapness is based on the large resources of coal, thick seams, and shallow mining depth which make mining very economical. Approximately 98% of the electricity consumed in South Africa is generated by ESKOM which is a parastatal body. Its technical excellence is accepted by its peers world-wide and it is one of the world's largest utilities. Over the years its role has changed. Some twenty years ago it considered itself a wholesaler to industry and to municipalities, with domestic distribution being carried out only where there was no adequate distribution network. This meant, for example, that most farms were direct sales, whilst most urban consumers were served by municipalities. With the present concern over rural and peri-urban electrification and the political problems associated with it, ESKOM has adopted the mantle of provider to individuals.

In view of future trends it is important to evaluate ESKOM in the total electricity scene, not only nationally but also regionally. It is also important that the role of ESKOM as a parastatal be adequately defined vis-a-vis the State. In the past there have been confrontations between ESKOM and the State where the State required ESKOM to carry out certain actions, such as limiting tariff increases, because of political requirements.

In view of the changing situation it is necessary to reconsider ESKOM's structure. Developments in electrification require a more logical arrangement for the interface between the smaller consumer and the electricity utility. In view of the diffuse nature of distribution, a regional approach could be adopted under the supervision of a central authority. The regional distributor would be the retail supplier to individual consumers. The central authority would be responsible for standards and for supplying expertise to the individual regions. Funding of sub-economic supply would be channelled through the central authority to the regional distribution centres.

In the future there is a likelihood of more imports from outside the country and there could also be a demand from individual small-scale generators to supply the nation demand. These two sources of supply would be in direct competition with ESKOM, and therefore a system should be developed to ensure that there is adequate competition between generators and that the national interest, in terms of minimal cost, is achieved. There should thus be a wholesaler of electricity who would not be a generator but would purchase electricity from the lowest source.

In view of ESKOM's role as an operator of large set sizes, it is obvious that ESKOM would remain as the dominant supplier, but such a system would allow the purchase of electricity from a number of sources, including from utilities outside the borders. Thus any hydro-generation from Angola, Namibia or Zaire would be by the wholesaler. The wholesaler would then transmit electricity in bulk to the individual regional distributors and to major consumers. Such a system would therefore consist of three components. Component one would be ESKOM and any other internal or external electricity generators. Component two would be the wholesaler which would control the major transmission system and would buy from the producers and sell to Component three: consumers or regional distributors.

Such a system would enable competition between generating authorities and would allow economies of scale in transmission. It would also allow for imports from, and exports to, neighbouring countries in order to achieve a minimum cost and to maintain security of supply. The division into regional distributors should occur as soon as possible since there is a backlog of electrification which needs to be addressed. The split between "generation" and "transmission" is not urgent and there is time to consider a rational distribution between ESKOM and the proposed transmission system.

A number of studies on the price of electricity in South Africa have advocated a cross-subsidization between various categories of consumer, basically to make large consumers subsidize the small consumer. Such a policy is bad in principle since it either requires strict and detailed control of electricity prices by government or else it allows the utility to cross-subsidize under its internal policy. This would lead to a distortion of market forces and to the sort of problems which are being faced by a number of African utilities. It would result in a utility being used by government to satisfy its social or political goals.

The provision of energy, water or housing to the developing sector of the country is a requirement of government. If it has to be supplied below cost, then it is government's prerogative to arrange this, but such an arrangement should be transparent and seen for what it is - a social obligation. Asking a utility to cross-subsidize tariffs is hiding the cost and distorting market forces. This sort of cross-subsidization is what used to occur with organisations such as the South African Railways where the cost of farm produce was subsidized by a charge on items such as coal for political purposes.

## 8.3 Coal

The coal industry is competitive because of the number of participants in the market. There is therefore no need to instigate any controls on the marketing of coal. However there is a need to ensure that from the national viewpoint the discard coals are utilized. A policy has therefore to be devised which will ensure the optimum use of the country's coal resources. Such a policy could include a levy on each ton of coal discarded. This levy could then be used to encourage the generation of power from discard coals.

In view of the poor quality of the discard coals, an environmentally acceptable system will need to be devised for its utilization. A system such as the use of fluidised beds with the use of dolomite would produce acceptable emission levels. In order for such a system to be economically optimized, collaboration would be required between the various suppliers of discards and large central plants could be considered. Power production could be utilized by individual organisations such as coal mines, but surplus supply would need to be fed into the national grids. The levy would need to cover the total excess cost of the system, i.e. the cost of coal recovery from dumps, conveying it to a central point if required, and the generation of power, minus the revenue earned from supplying power at the average cost of the grid.

With the closing of the Transvaal Coal Owners Organization (TCOA) by the Monopolies Board, there is no longer a central body capable of providing technical assistance to customers and of collecting statistics for planning purposes. There is thus no avenue for promoting coal as an energy source nor of promoting energy efficiency in the coal utilization sector. Coal is therefore at a disadvantage in comparison with energy sources such as electricity, and there may well be scope for energy substitution by coal in the national interest. At present the only source of information is the CSIR, and they are more geared to research than to providing information of a practical nature. It is therefore considered that the technical components of the old TCOA should be reconvened in order to provide a service to coal consumers.

The most important environmental problem in South Africa is due to the use of coal in households in townships on the Highveld. Various research has been carried out on the effects of electrification, the use of smokeless fuel, and the use of smokeless stoves. All attempts to improve the situation have failed due to the perceived need for coal stoves, the apparent cheapness of coal compared with other sources, and the inability of electricity to replace coal as a heating and cooking source even where electricity has been supplied. In view of these failures it is suggested that a concerted drive be undertaken using all the available options such as smokeless stoves and fuel, and that an educational campaign be mounted to use electricity where available. Financial incentives may be required to ensure that where electricity is available it is used for heating and cooking. Such incentives could, for instance, include a cash payment for a householder who trades in a coal stove for an electric stove.

Coal exports are likely to be an increasingly important foreign exchange earner in the future and it is necessary that the infrastructure for such trade be timeously available. The provision of such infrastructure is the responsibility of the relevant organisations such as the mining houses, railways, harbours, etc., but it is important that a watching brief be set by government over this matter to ensure provision of services in the most nationally effective manner.

## 8.4 Petroleum

The most pressing problems for government in the area of liquid fuels supply and demand concerns the deregulation of the industry and the regulation of vehicle emissions. The latter problem will be considered in a separate section.

It is accepted that the petroleum industry has to be deregulated. Further, the presence of the synthetic petroleum industry, which was formed because of strategic considerations, complicates the situation. Cost calculations have shown that the synthetic liquid fuels industry is not competitive with crude-based petroleum. However the capital commitment has been expended, and closing down these plants would not recover any capital and would, in fact, be associated with additional costs. It is therefore only necessary to look at the operating cost of the projects in order to determine whether they should be closed.

A study of the controversial MOSSGAS plant has shown that the plant revenue exceeds operating expenditure, and therefore there is no justification for closing MOSSGAS based on straight economic grounds. In terms of the foreign exchange savings and the sociological aspects of job creation, there is a positive benefit of maintaining production from MOSSGAS. A similar argument is applicable to SASOL, and the job creation aspect is even more important because of the large number of jobs that have been created, especially in the mining sector. Therefore there are no grounds for closing down SASOL especially since SASOL is moving progressively into chemical production.

Since there are no economic or other grounds for closing down either SASOL or MOSSGAS, the question becomes one of what subsidy should be paid to these two bodies in order to make them competitive with the other liquid fuel suppliers. Theoretically the sunk cost should be covered by the government and the two bodies should be operated as non-profit organisations, any profits being used to cover the government's share of sunk costs. However it is most probably more efficient and in country's interest to leave the management of the two organisations in the from that they are now. The question becomes one of what is the best base charge that should be used for the basis of costing the equivalent import price of synthetic fuels.

In addition to the consideration of synthetic fuel cost, there is the concern with discounting of fuel by large stores. If fuel supply is allowed to all possible outlets, the position of the oil companies and the role of the synthetic fuel industry become very problematic, especially if importation of refined products such as gasoline and diesel is allowed. It is not in the national interest that refining capacity, which has been installed with local funds, should be under-utilized, whilst finances are expended on foreign value-added fuels. It is obvious also that if supermarkets and similar organisations market fuel at a discount, it will invariably lead to cross-subsidization from other sources. It is therefore highly probable that liquid fuels would be used as loss leaders and the cost would be borne by food products. In view of the importance of food prices to the large low-income sector of the population in South Africa, it is considered that fuel supply by organisations whose primary purpose is the supply of commodities such as food, clothing, etc., should not be permitted.

In comparison with most other countries in the world, there is an imbalance between gasoline and diesel prices in South Africa. Since diesel fuel is used almost exclusively in the economic sector of the country, whilst gasoline is used in both the economic sector and in the non-productive sector, there should be a lower tax on diesel fuel than on gasoline. Such a change in tax would result in redressing the present imbalance between diesel and gasoline in terms of the supply capability of the refineries. An increase in the price of gasoline and a reduction in the price of diesel would also result in more people using diesel vehicles especially in such applications as kombi-taxis. In Europe there is a growing move to diesel engines, with countries such as France having a 40% diesel passenger vehicle fleet. Increasing the number of diesel vehicles, especially amongst that section which are the largest users of fuel, would result in an overall increase in the efficiency of fuel utilization, due to the higher efficiency of diesel engines compared with spark-ignition engines. On a national basis this would result in a decrease in crude import, a decrease in the cost of transport, and a reduction in the inflation rate.

Because of past experiences where price increases have resulted in political action, the change in the relative taxation on gasoline and diesel would have to be carefully planned and the benefits of diesel engines would need to be spelt out and demonstrated to significant groups such as the kombi-taxi operators.

The disposal of used lubricating oil is a pollution problem which has reached a serious level and methods of collecting used oil and its disposal are currently being studied. Some suitable legislation may be required to facilitate an environmentally acceptable solution.

## 8.5 Demand-side management

It is often said that South Africa uses energy inefficiently, and that this can be proved by the high energy intensity that South Africa has in comparison with its Gross Domestic Product. This high value can partly be ascribed to the sectorial mix of its economy and its high proportion of primary industries. However the energy efficiency could be increased in line with increases in other countries. Improvements in energy efficiency in other countries are linked to governmental efforts. Such action in South Africa is largely absent. It is estimated that with adequate governmental support, energy savings amounting to 30% of total energy usage could be achieved by 2020. In the short term approximately 10% of energy could be saved with minimal capital expenditure. A 10% saving in energy use would represent an increase in GDP of approximately 1% or R 3 Billion.

In order to realize the savings that are possible by demand-side management, there has to be a concerted effort on the part of government to provide the framework for an active energy efficiency programme. This should include an educational aspect, should include energy audits, and should provide for a system of incentives to industry since it is in the national interest.

## 8.6 Environmental factors

There are three main areas of concern relating to the environmental aspects of energy supply and use. The first of these concerns the serious pollution problems being experienced in the townships, mainly on the Highveld, during winter, due to the use of coal in domestic stoves. This topic has already been discussed under the heading of "coal". The problem requires a vigorous multi-pronged action including the provision of smokeless stoves and fuel and the electrification of these townships. However electrification is not an answer unless it is combined with incentives for the inhabitants to move from coal stoves to electric stoves and heaters.

An increasing problem in South Africa is pollution due to transport activities. At present there is legislation only on the emission of black smoke from diesel engines, but even this legislation is ineffective because of lack of implementation. There is a growing problem in some cities of photochemical smog production due to the emission of volatile organic compounds and nitrogen oxides. No estimate has been made of the situation in South Africa and no attempt has been made to estimate the problem in the future under various scenarios. What action in this connection that has been taken in the past has been made without adequate assessment of all the effects. For instance, the introduction of unleaded gasoline was made for political expedience without considering possible deleterious results of such a decision.

Following the lead of most other developed countries, and a growing number of developing countries, consideration must be given to legislation limiting the level of emissions from passenger and commercial vehicles. This will undoubtedly lead to the requirement for emission control equipment on gasoline engines, but consideration will have to be given to the method of implementation since the provision of, for example catalytic converters, will mean a significant cost penalty to the economy.

Consideration will also have to be given to the formulation of legislation to limit evaporative emissions from the whole of the liquid fuels chain from refinery to the vehicle.

Cognizance must also be made of potential alternative transport systems such as electric vehicles, and to the whole question of transport modes. At present most planners put their hopes for a more environmentally acceptable situation on catalytic converters. However because of the long lead time and inertia in the introduction of such measures as converters, consideration must be urgently given to other ameliorating measures such as good road planning, traffic control, etc.

The third environmental problem concerns the generation of electricity, especially in the Eastern Transvaal. Whilst monitoring of pollution levels has been carried out over a number of years by ESKOM, there has not been an adequate analysis of these pollution levels by an independent authority. It is suggested that a monitoring commission be appointed by the government and paid for out of funds provided by ESKOM, or by a levy on electricity, to analyse the available information on pollution levels and to determine whether additional power stations of the present type can be constructed in the Eastern Transvaal, or if desulphurisation or de-$NO_x$ control measures have to be incorporated. In view of the high cost to the country of the requirement for environmental measures such as the installation of de-$SO_x$ and de-$NO_x$ systems, careful consideration must be given in the determination of the maximum permissible pollutant levels and in the analysis of the existing levels and forecast increases due to new power plant.

## 8.7 Nuclear power

Koeberg has now been operational for 10 years. Recent discussions on its future have been associated with an emotional appeal to close it down because of safety fears and because of the perceived relationship between commercial nuclear power and military weapons applications. It is important to reassure people that there is no imminent danger in the operation of Koeberg. If it can be shown that electricity from Koeberg is more expensive than generation on the Highveld and transmission to the Western Cape, then a case could be made for the closure of Koeberg. However the closure of Koeberg would require capital investment in a further plant, whilst the capital for Koeberg has already been incurred. It is therefore evident that the closure would be expensive to the country at a time when funding is required for a large number of other social investment.

In order to ensure that Koeberg is operated safely, a strong and effective control body is required. Such a body, the Council for Nuclear Safety, already exists and it must be strengthened in order to ensure that it operates efficiently and impartially. One of the problems that will be faced by the Council is that it is at present responsible to the Minister for Mineral and Energy Affairs. It is therefore the prerogative of one person to appoint the members of the Council and to determine the rules of operation of the Council. A wider responsibility is required and possibly the Council should report to the Cabinet, or a committee of the Cabinet. A committee of the Cabinet made up of the Ministers responsible for Health, Environment, and Energy, would be preferred .

The safety of the nuclear plant depends on a adequately trained and highly motivated staff. Any perception that the plant will be closed down will be highly demotivating to the staff and could affect the optimum and safe operation of the plant. If any investigation is required on the economics of the plant, it should be done as quickly as possible in order not to allow staff morale to deteriorate.

Any health regulations applicable to a nuclear plant should be based on internationally accepted norms and should not be set at levels proposed by individuals with no standing amongst the peer international community.

## 8.8 International affairs

The South African energy industries have to operate within the ambit of world norms. Until recently such norms only affected trans-border operation. Thus coal exports had to operate in the international market and had to conform to international regulations concerning aspects such as safety of shipping, etc. Increasingly, there is pressure on the internal energy sector to conform to international norms in terms of environmental conditions. Increasingly exporters of manufactured goods are being subjected to questions concerning the environmental conditions under which their goods are being manufactured. For example, the world concern with global warming is impacting on the $CO_2$ emission standards of individual countries.

In many of the environmental problem areas it is the developed world which produces most of the pollution and has, moreover, developed its wealth ignoring environmental pressures which were unknown at that time. It is difficult therefore for the developing countries to agree to limits set by the developed countries which would have the effect of decreasing economic development. Thus it is important that South Africa strikes the right balance between meeting the requirements of the developed world as well as those for economic growth in the country and in the region.

A policy therefore needs to be developed for South Africa which would allow the country to react proactively to world pressures, at the same time doing no more than is required and to minimize the impact of any such actions on the economy.

## 8.9 Social costs of energy

It has been shown that the external costs of energy, i.e. those costs which are a cost to the country but are not included in the energy price charged to customers, should be included in the energy price in order to adequately reflect the true cost. The evaluation of these external costs is problematic but should be attempted in order, firstly, to determine whether there is a case to be made for investing in alternate energy forms and, secondly, to cover the true energy costs to the country and to allow different energy forms to compete on a level basis.

## 8.10 Research

Policy cannot be made in isolation and has to rely on an adequate information and research base. In a developing country such as South Africa it must be realised that the role of research has to be more circumscribed than in more developed and richer countries. However this must not be taken to mean that all research has to be of a short term and contractual basis. There has to be balance between short-term and longer term research, and in particular there has to be a process of evaluating what is happening in other countries.

One of the problems of energy research in the past has been the stop-start nature of the work resulting in a lack of continuity. There has not been any possibility of a career path in energy research.

It is therefore necessary that a policy for research is developed which would include the aspects of short-term and longer term research and would steer the country's research in the main streams of energy supply and demand. A system of research funding is required which will allow for continuity and will develop the skills that the country will require for the future.

## 8.11 Government structure

In view of the importance of energy to the national economy and its role in the upliftment of people, it is important that the government has a strong energy policy and management sector. It is important that this sector be a facilitating service with a minimum of regulatory authority. The sector requires a policy-making body supported by a research and information organization. This research group should not itself be relied upon to provide a significant amount of research work, but should guide and initiate research amongst the various appropriate bodies in the country.

The policy-making arm of government has to be firmly embedded in a Ministerial Department, but for optimum efficiency the research arm should be set up as a parastatal body along the lines of the defunct National Energy Council.

# CHAPTER 9. CONCLUSION

## 9.1 Introduction

The attempt has been made to estimate the future growth of energy use in South Africa against a scenario of economic GDP growth rates from 3% to 5% per annum. In the analysis of the energy requirement it has been assumed that there will be an increase in energy effectiveness, the increase depending on the assumed economic growth. Thus the concept of energy intensity, the amount of energy required to produce a Rand of GDP, is an important one. It has been shown that the increase in effectiveness can be very strongly influenced by government intervention.

## 9.2 Coal

It is forecast that coal's share of the final energy consumption in South Africa will continue to decline to a final figure of 34% by the end of this century. Total tonnage will continue to increase to a figure off around 480 million tons per year by the middle of the next century. Coal exports will increase in line with world demand and could rise to 160 million tons per year by 2020. If after 2020 the export of coal is limited, then export coal should only be a small portion of total reserves and therefore exports should not adversely affect the country's own needs. Discard coal will be a large proportion of total coal production, and government intervention is required to ensure that discard coals are utilized for energy production and not left on discard dumps.

The environmental problem of coal use for domestic consumption will need to be addressed as soon as possible. It is considered that a multi-pronged attack is required on this problem since no one action, such as electrification, will be sufficient to adequately redress the health problem.

## 9.3 Electricity

Electricity's share of the total energy market will continue to increase from its present share of 28% to a saturation level of 32% early in the next century. The total growth in electricity sales will be affected by the growth in the economy and also by possible measures adopted by the government to increase demand-side efficiency in energy utilization.

It is considered that the electricity industry should be restructured into three main components: generation, transmission, and distribution. Distribution should in turn be structured to allow for an overall planning body which provides support skills and sets standards for a number of regional distribution authorities.

The transmission authority should act as a wholesaler of electricity, purchasing from the generation authority (the present ESKOM) but also able to purchase from individual suppliers and to arrange imports from surrounding countries.

A large effort is required to provide electricity to those people without access at present. The funding for this, where it is uneconomical at present in a reasonable time-scale, should be provided from central government. It is considered highly undesirable for an electricity utility to carry out any "cross-subsidization". Any assistance for electrification for socio-economic reasons should be carried out by government and must be seen as such and not hidden in the total electricity funding.

It is estimated that the present surplus of electricity will disappear around 2003, assuming that all the moth-balled stations have been brought back into service, that Cahora Bassa is available, and that all the power stations at present on order are completed. Thereafter the capacity shortage will increase rapidly, especially since a number of stations will need to be decommissioned after that date. By 2010 there will be a need for 11 000 MW of additional capacity and 24 000 MW by 2015. Since the last coal-fired power station will most probably be built in around 2015, alternative sources of electricity will be required. Some of this additional capacity could be from imports from countries in sub-equatorial Africa. However the amount of imports is limited by considerations of electrical stability on the transmission lines and by considerations of energy security in political terms, and it is estimated that by 2010 this import capacity would be less than 10 000 MW and no more than 14 000 MW by 2015. Thus, whilst imports will be an important constituent of electricity demand in the future, indigenous capacity will also be required.

The environmental effects of electricity production, especially in the Eastern Transvaal, need to be assessed as soon as possible in order to allow for adequate planning for the future. In view of the high cost of introducing flue gas desulphurization, and the even higher cost of installing nitrogen oxide control equipment, it must be seen that such measures are necessary for sound environmental reasons.

In view of the large amounts of coal still available in the Eastern Transvaal it is important that the country expands its research effort into clean-coal technologies.

It is also necessary that the environmental costs (the so-called externality costs) for the generation of electricity by the various means: coal, nuclear, hydro, solar, and wind, should be determined. Such costs should then be included in the cost of electricity in order to take account of the true cost of generation to the country.

In view of statements made on the cost of nuclear energy, it is important that the cost of decommissioning Koeberg and its replacement by an alternative form be determined as soon as possible. Insecurity of staff at Koeberg could reflect adversely on the ability to operate Koeberg safely and satisfactorily for the remaining life of the station.

## 9.4 Liquid fuels

Liquid fuels are expected to maintain their share of the total final energy consumption at 33%. At present there is an imbalance between the quantities of diesel and gasoline consumed. Compared with other countries it is considered that the tax on diesel fuel is too high compared with that on gasoline. A decrease in the tax on diesel fuel would increase diesel consumption. This would, in turn, allow better operation of refinery capacity and would benefit the country due to the higher efficiency of diesel engines and thus lower crude imports. It is considered that it is necessary to promote the use of diesel fuel amongst kombi-taxis in order to decrease commuter costs.

The petroleum industry needs deregulation, but this has to be carried out in an orderly manner in order to preserve jobs in the retail industry and to ensure that no undue price increases occur in the medium. It is proposed that the industry be deregulated, but that an arrangement be made to prevent the use of self-service pumps for a period of, say, five years. Moreover, to prevent the increase in the price of food-stuffs, it is recommended that outlets selling mainly non-motor goods, and especially food and clothing stores, should be prohibited from selling liquid fuels.

Consideration must be given to the environmental effects of the use of diesel engines in underground mining operations.

Government incentives are required to the industry to ensure that used lubricating oils are recycled and are not disposed of by methods which are environmentally unacceptable.

It is considered that there is no case to be made for the closing of either the SASOL or MOSSGAS plants. It is considered that it is in the national interest to maintain these plants if the operating cost is less than the market price. A mechanism must be worked out to determine the recovery of capital cost from the operation of these plants and this will need to be related to the total cost of the price of crude-based fuels.

## 9.5 Gas

No estimate has been made of the share of gas in the energy market in the future since this depends on international agreements and on financing. Gas is available from the Kudu field off Namibia and the Pande fields in Mozambique. It is likely that, in line with overseas experience, the gas share could be approximately 15% in the time-scale considered. This share would be at the expense mainly of coal and to a lesser degree oil, though there will also be some competition for electricity.

## 9.6 Motor vehicles

Motorcar ownership has been growing in South Africa and has doubled from 45 passenger vehicles per 1000 of population in 1960 to the present 90. The environmental effect of the motor vehicle will thus increase, especially in the major cities, and some form of legislative control will be required shortly. Planning for this must start as soon as possible.

There is an imbalance between diesel fuel and gasoline usage in South Africa, as discussed above, and consideration should be given to methods of increasing the use of diesel engines, especially in sectors such as the kombi-taxi fleets.

## 9.7 Traditional fuels

There is currently a lack of activity in the making of policy to satisfy the energy requirements of those people who are far from an electricity grid and are unlikely to be connected to the grid in the medium term. With a decreasing amount of firewood, the energy problem is becoming serious in the rural areas and rapid action is required. It is unfortunate for the people affected that their need is not highly visible and is not considered a "vote-catcher". Thus prominence is being given to the need for electrification, but little is being done for "woodification".

## 9.8 Policy matters

Policy-making in the past has been unco-ordinated and has been largely ad hoc, with much of the strategy in the last two decades being dictated by security considerations. Because of the security aspects there has been a large amount of largely unnecessary secrecy. It is important that energy policy should be carried out in an holistic nature, taking account of energy, economic and environmental matters. It is important however to ensure that governmental interference is minimal and, where legislation is considered, it must be for long-term national considerations and for environmental issues. The African continent is replete with examples of the adverse effects of governmental control.

It is considered that the following policy matters should be considered:

### 9.8.1 Coal

(a) A policy should be developed to ensure the optimal use of discard coals in the national interest. A levy on each ton of coal discarded could be introduced and a subsidy could be given to anyone utilizing discard coal for energy production in order to make it economic.

(b) Consideration should be given to ensuring that the infrastructure is adequate in support of the long-term export potential.

(c) An analysis should be made of the pollution levels in the Eastern Transvaal due to coal-fired power stations in order to determine under what conditions further coal-fired power stations can be constructed in this area.

(d) An independent body should be set up to monitor air pollution levels in the Eastern Transvaal, and to advise on future control needs.

(e) A strategy should be developed to minimize the effects of the use of coal for domestic applications on the Highveld.

(f) In view of South Africa's extensive reserves of coal and its large reliance on coal as an energy source, significant research is required into improving the efficiency of coal utilization. In particular, more work is required into the introduction of clean-coal technology.

### 9.8.2 Electricity

(g) Consideration should be given to restructuring the electricity industry in three sections - generation, transmission, and distribution. The "transmission" section should be a wholesaler of electricity, purchasing electricity from a range of generators, including imports, and selling to distributors. The distribution sector should consist of an overall planning and standard-setting body with regional components.

(h) The cost of nuclear power and the cost of closing Koeberg should be determined as soon as possible and a decision made on the future of Koeberg.

(i) The Council for Nuclear Safety should be given effective powers to ensure safe operation of nuclear plant. The Council should be made responsible to the State President through a Cabinet Committee consisting of the Ministers responsible for energy, economics, and environment.

(j) The externality cost of electricity generation should be estimated and internalized into the electricity price. This would ensure that the market pays the true cost of electricity.

(k) The process of electrification should receive top priority, but the funding for it should come from government sources where a project is uneconomic in utility terms.

### 9.8.3 Liquid fuels

(l) The petroleum industry should be deregulated subject to certain conditions such as an embargo on self-service pumps for a period of time.

(m) An embargo should be placed on the distribution of fuel by organizations which are primarily concerned with other commodities such as food, clothing, etc.

(n) A system should be introduced to ensure that used lubricating oils are recycled and not discarded in ways that are environmentally unacceptable.

(o) The tax on diesel fuel should be reduced relative to that on gasoline in order to redress the imbalance between the two fuels, and to reduce inflation.

(p) A subsidy system should be introduced to ensure that SASOL and MOSSGAS continue in operation, but in a manner that does not impact unduly on the profitability of the petroleum industry.

### 9.8.4 Research

(q) Research into energy matter should be formalized to allow for continuity. Research should be funded through levies on energy and should be administered by a statutory body such as a National Energy Council.

### 9.8.5 Demand-side management

(r) In view of the potentially large savings to the country, a vigorous programme to encourage effective use of energy should be introduced.

## 9.9 Conclusion

Policy on energy matters has been fragmented and largely carried out under conditions of urgency. Much of the policy has also been made on the basis of security under a sanctions situation. There is now an ideal opportunity to formalize policy-making, basing it on adequate research and pro-actively.

It must be remembered that policy should be made against the background of short -, medium-, and long-term requirements. Policy plans must therefore be drawn up to include the three time-scales, and research should be aimed at an understanding of the factors that impinge on energy policy in each of the periods.

## 9.10 Acknowledgements

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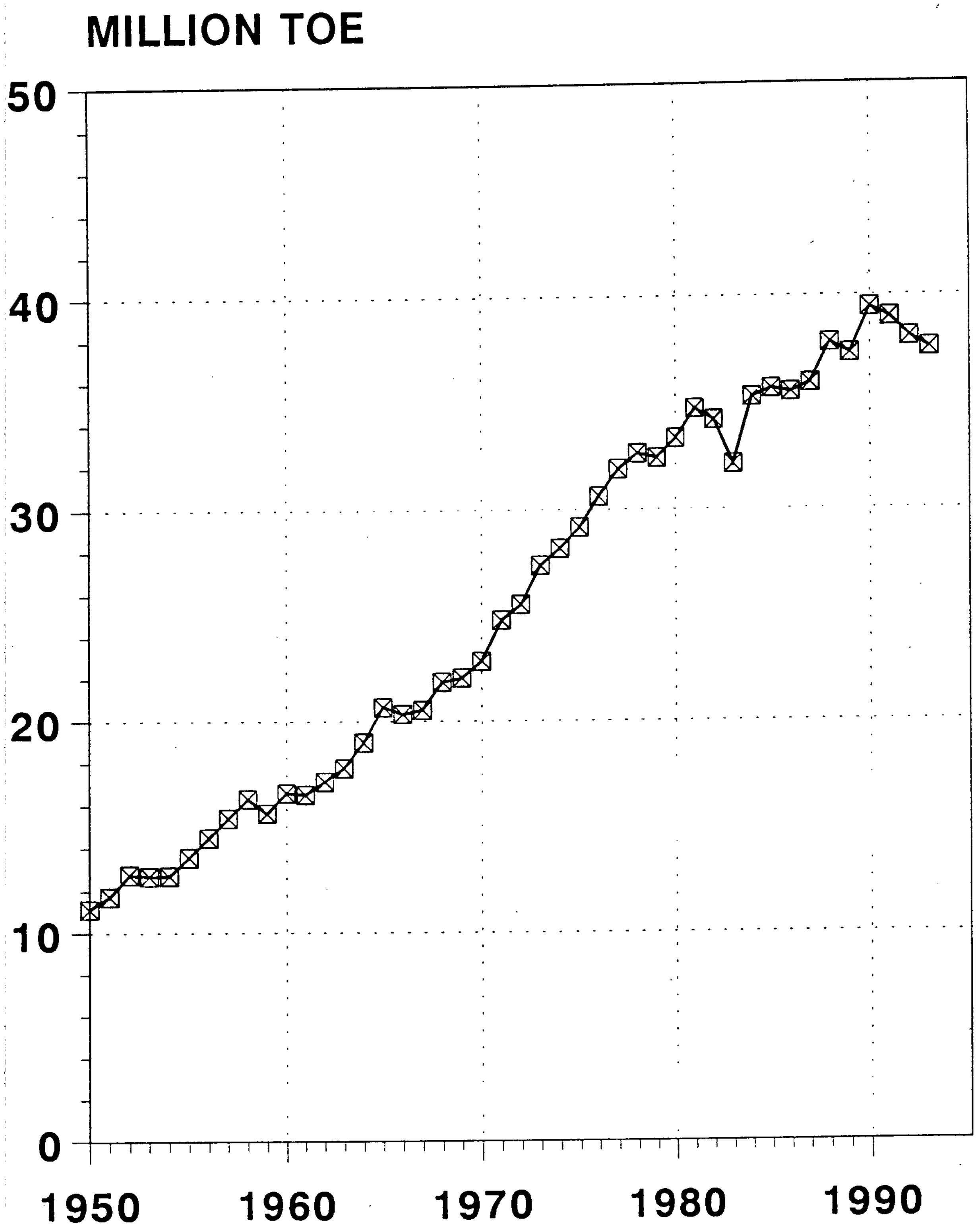
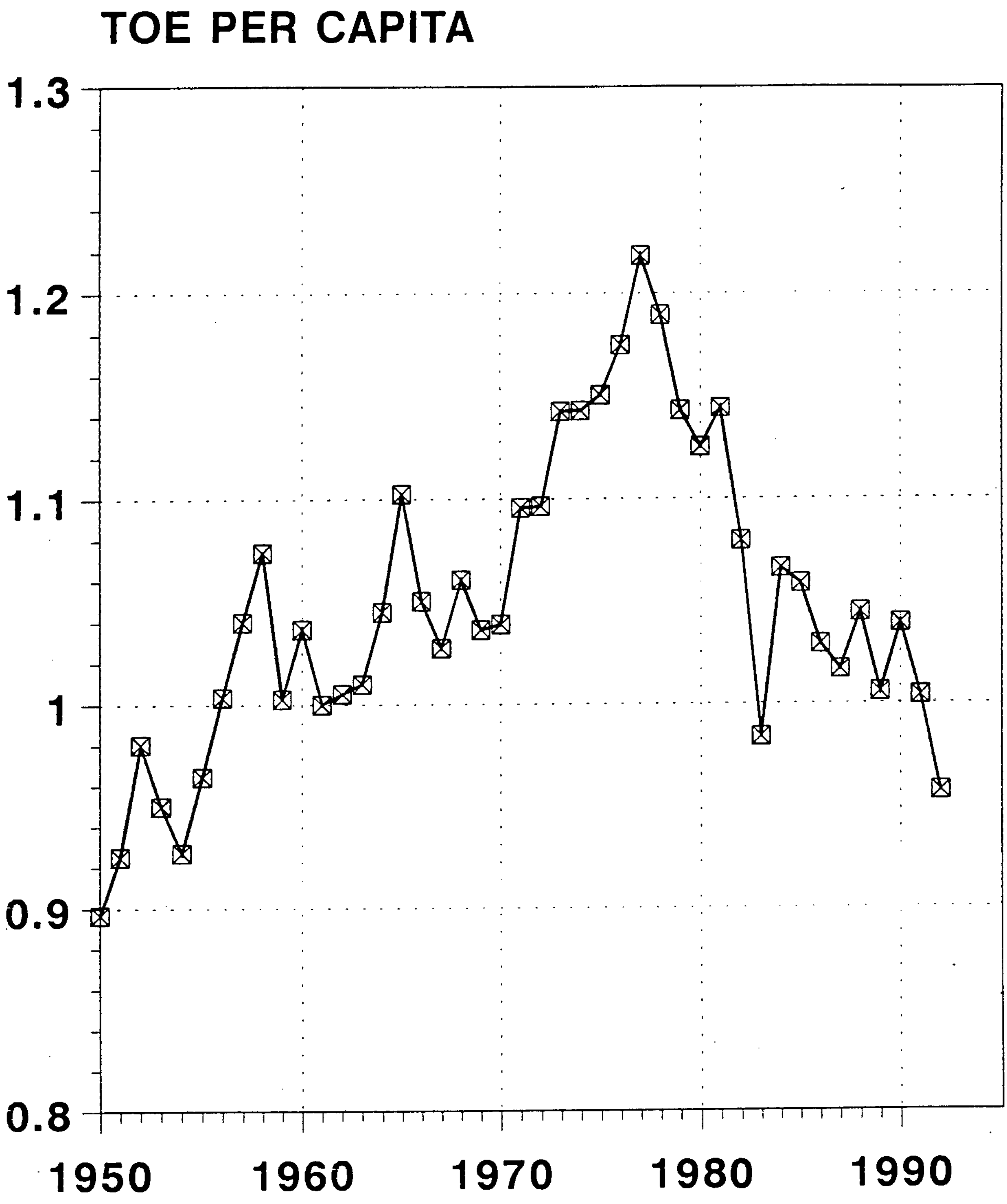
# FIGURES

Figure 2.1 Total final consumption of commercial energy



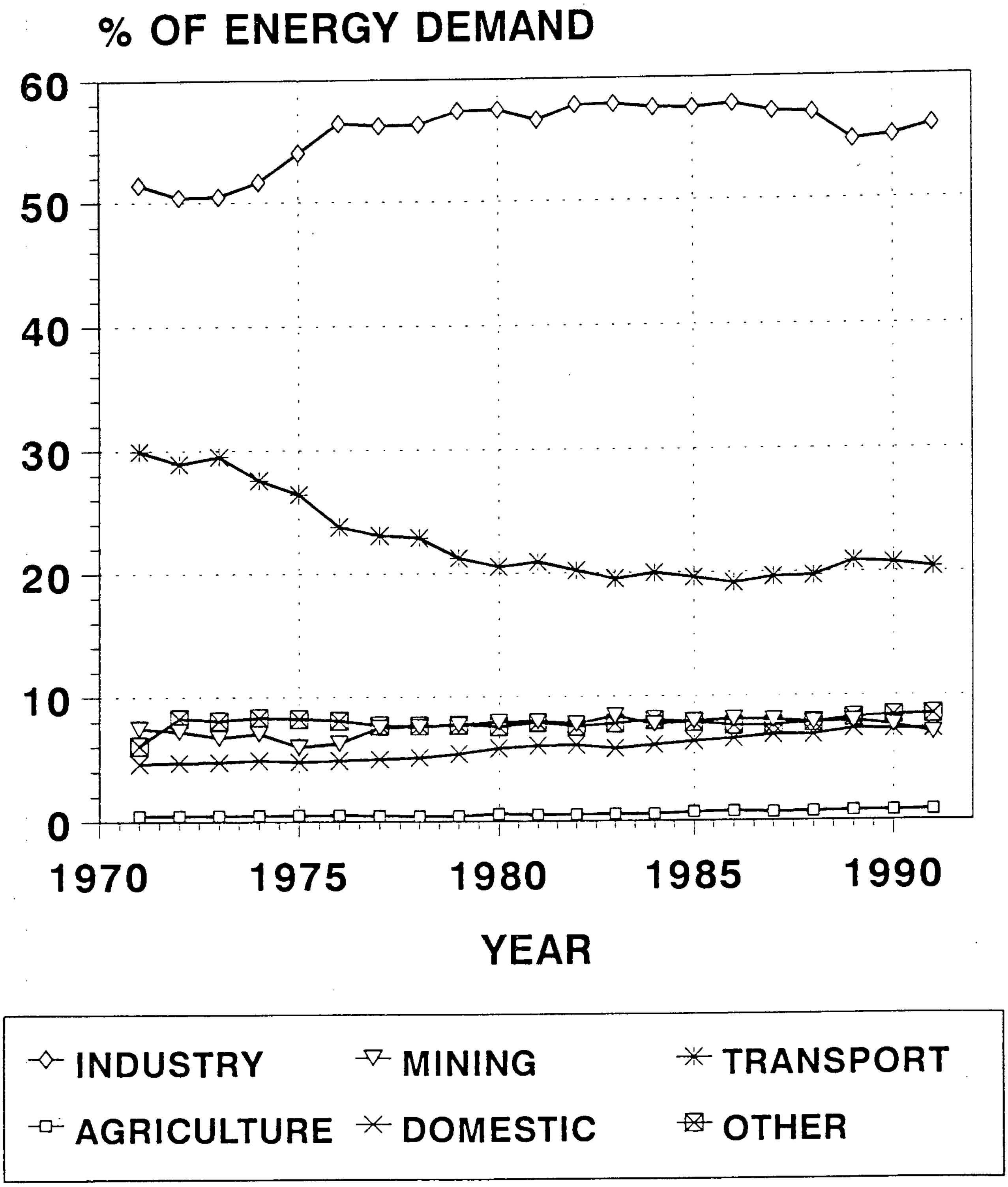

SA 2.1

Figure 2.2 Per capita consumption of commercial energy




;A 2.2

Figure 2.3 Contribution of final commercial energy by economic sector




SA 2.3

Figure 2.4 Energy per capita versus GDP per capita (traditional plus commercial energy)

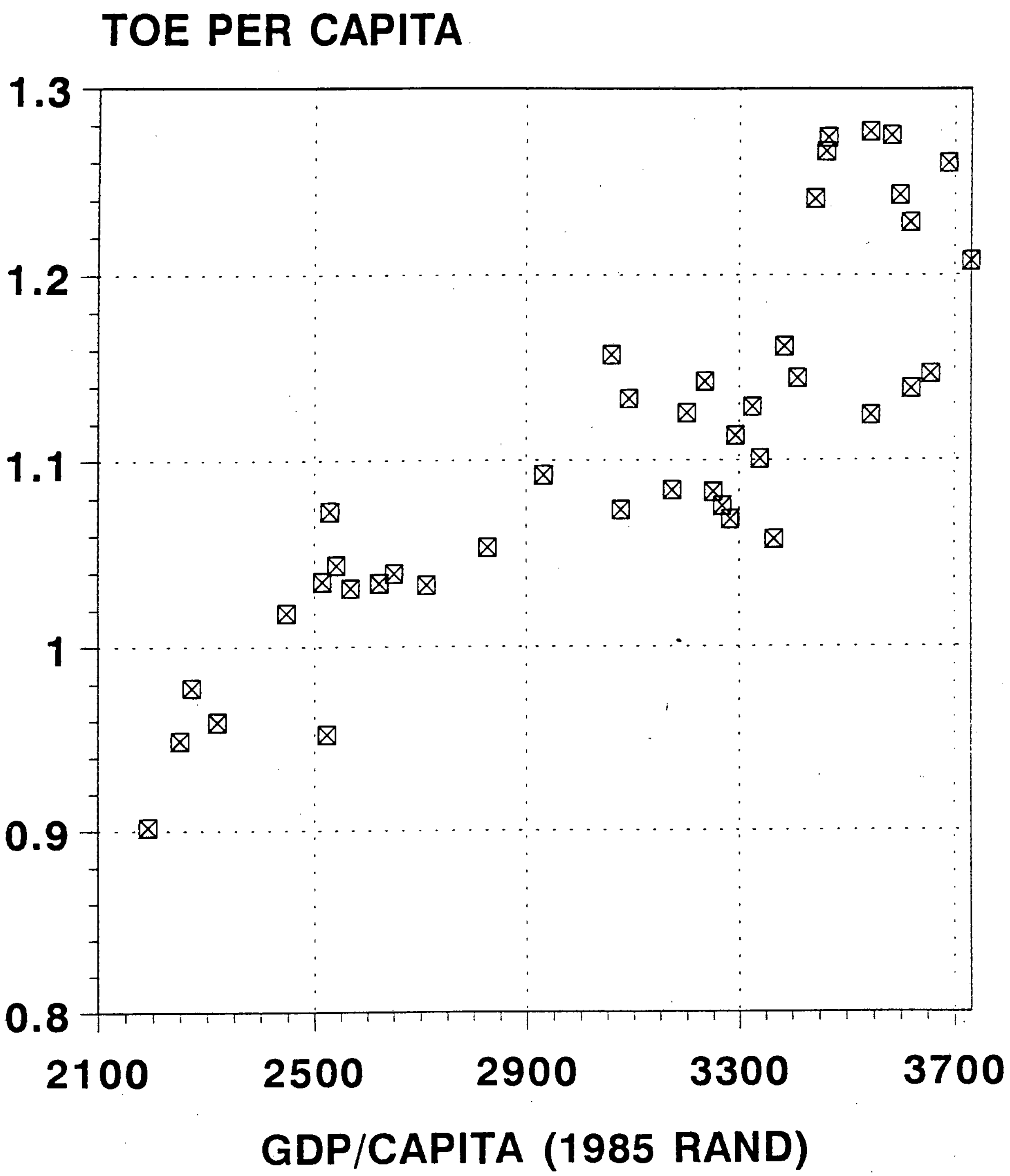
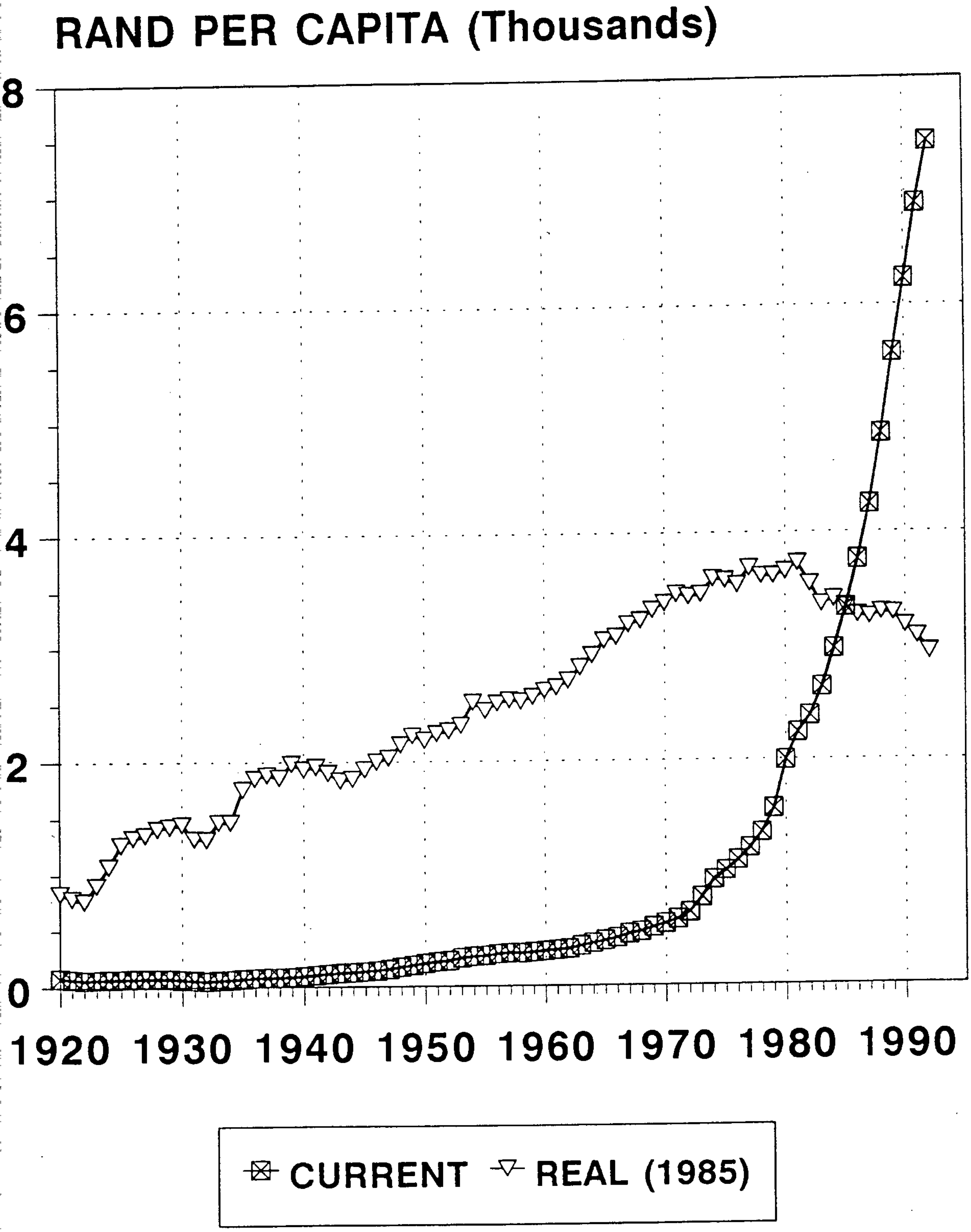
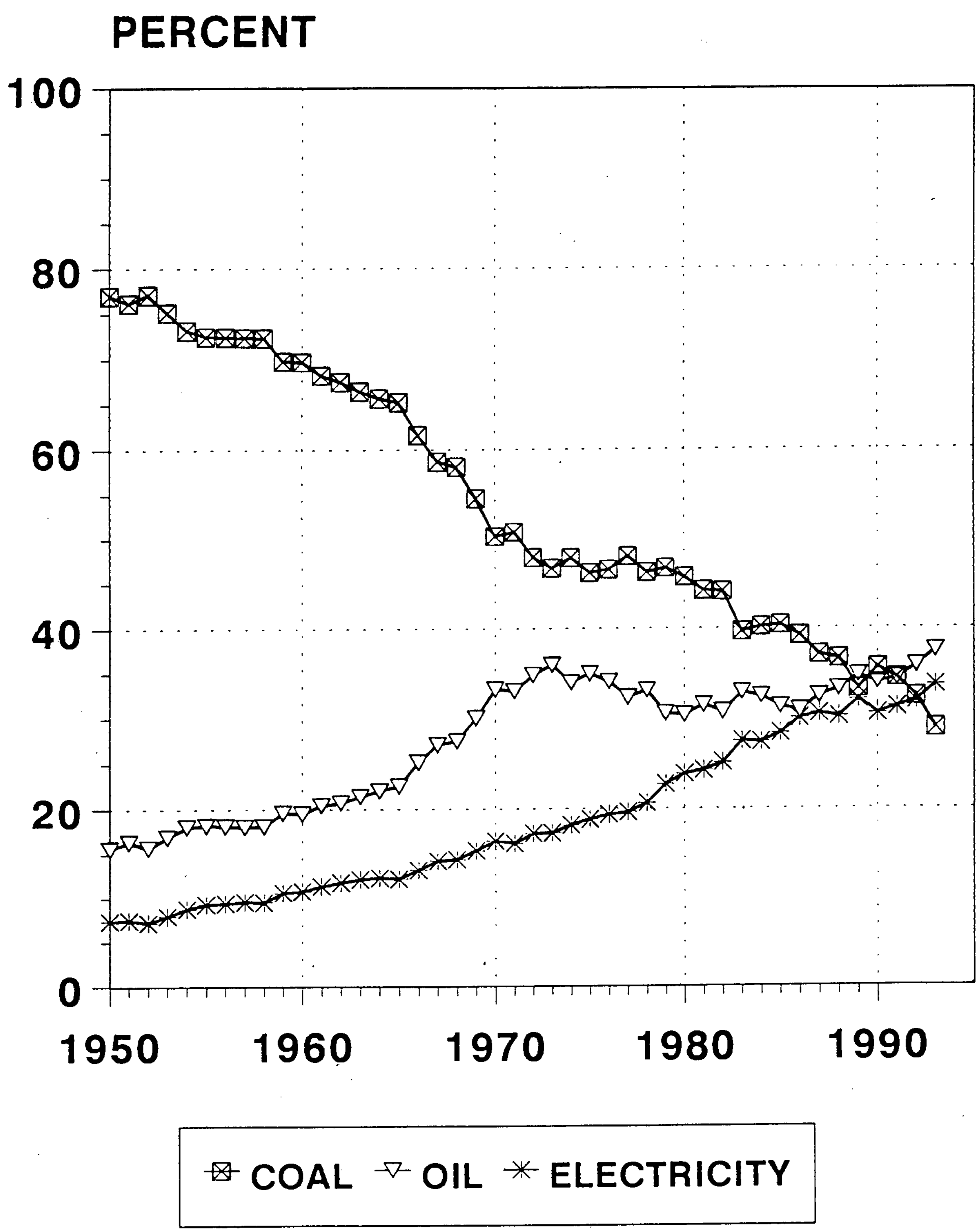


Figure 2.5 Real GDP per capita



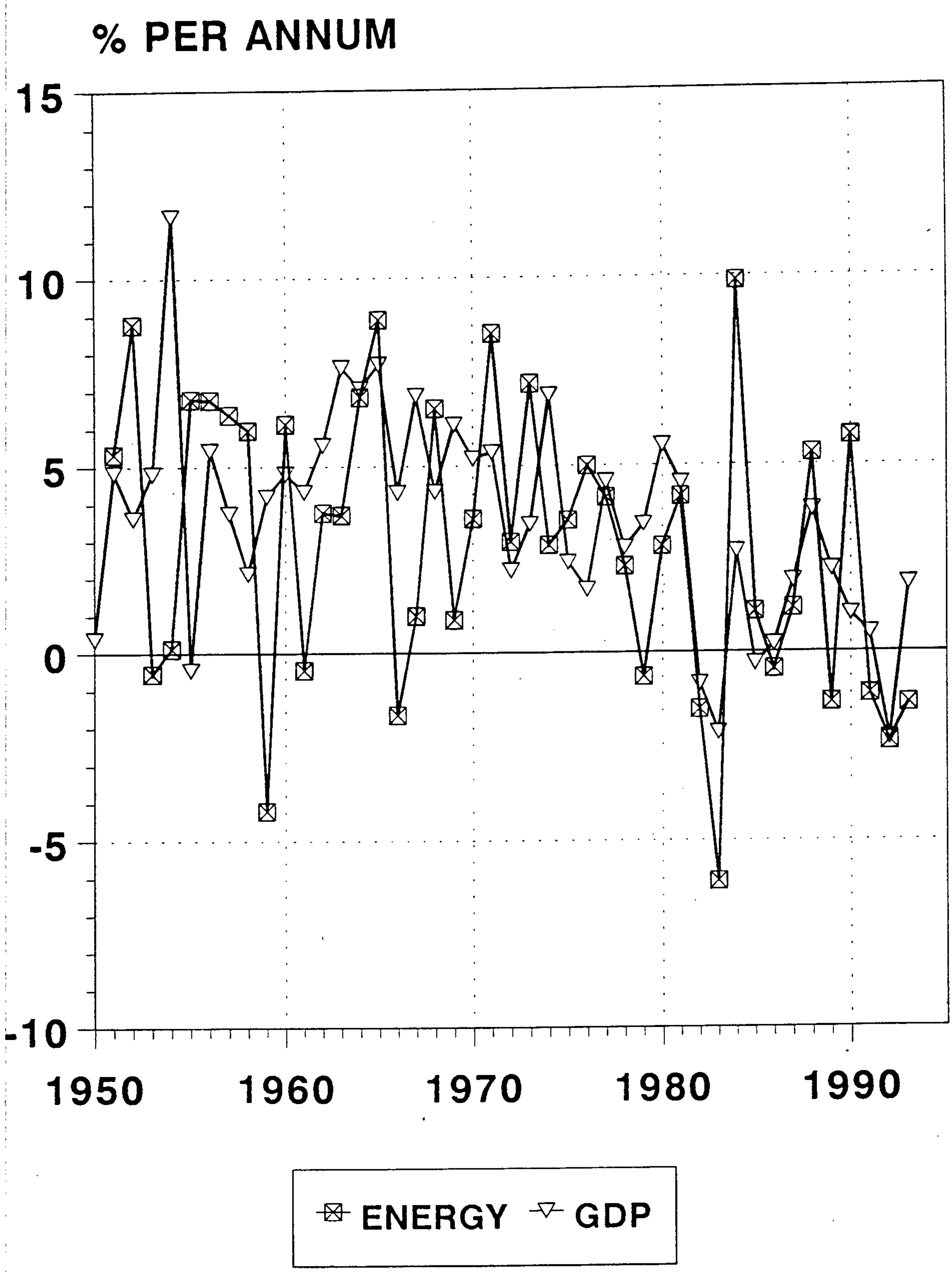

2.5

Figure 2.6 Market share by energy form of total final energy consumption



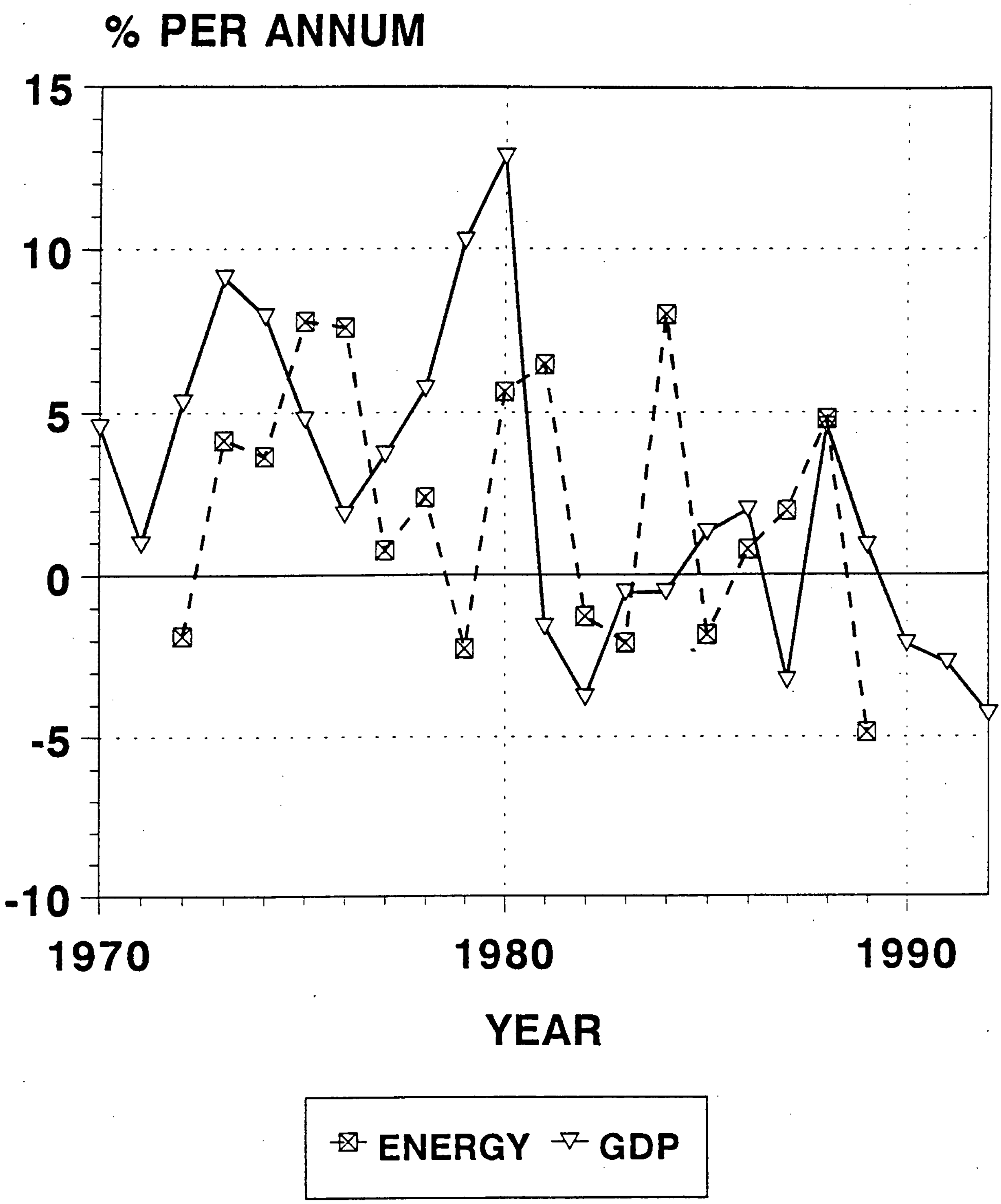

A 2.6

Figure 2.7 Growth in GDP and in final energy usage



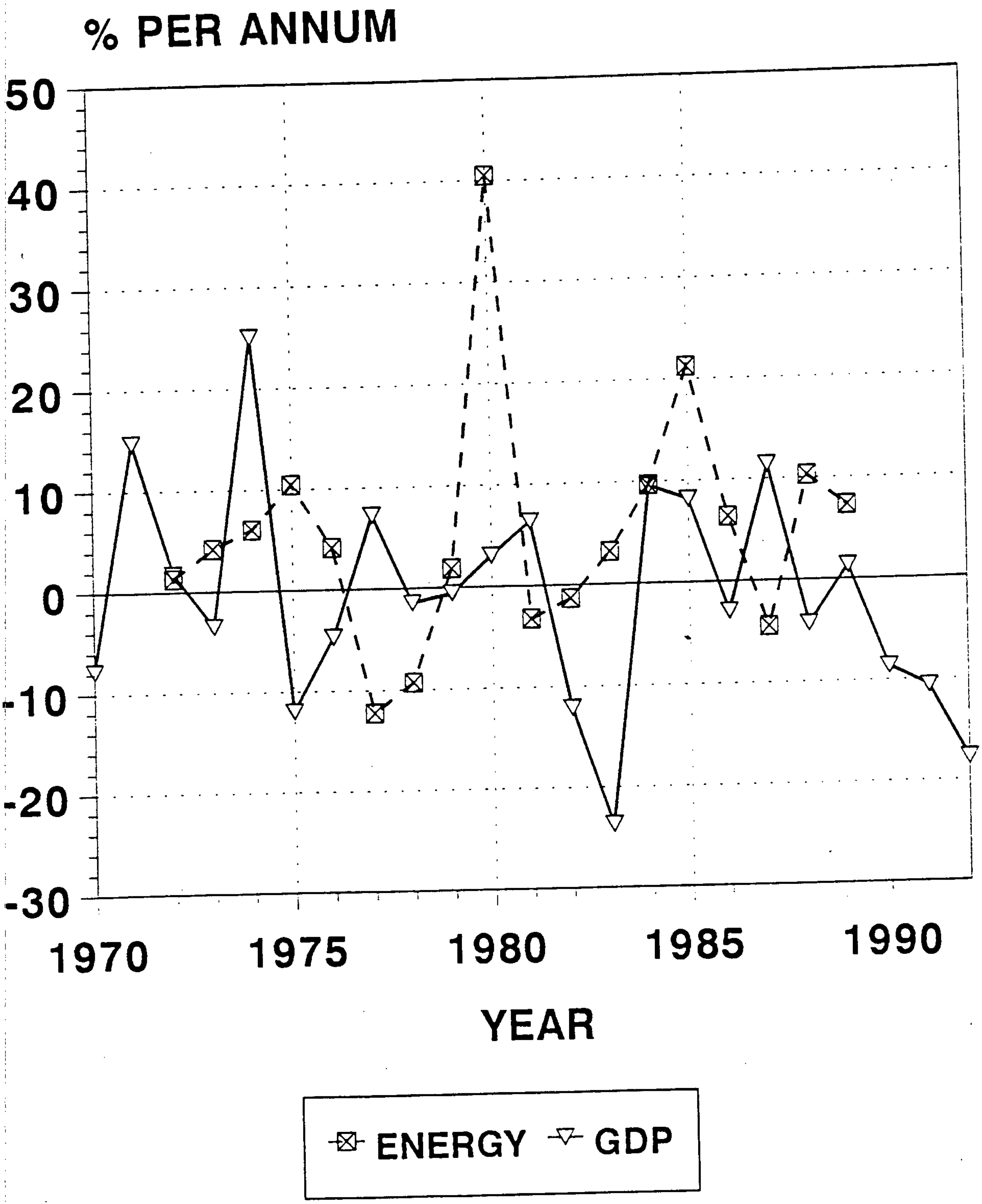

SA 2.7

Figure 2.8 Industrial sector growth rates of GDP and energy usage



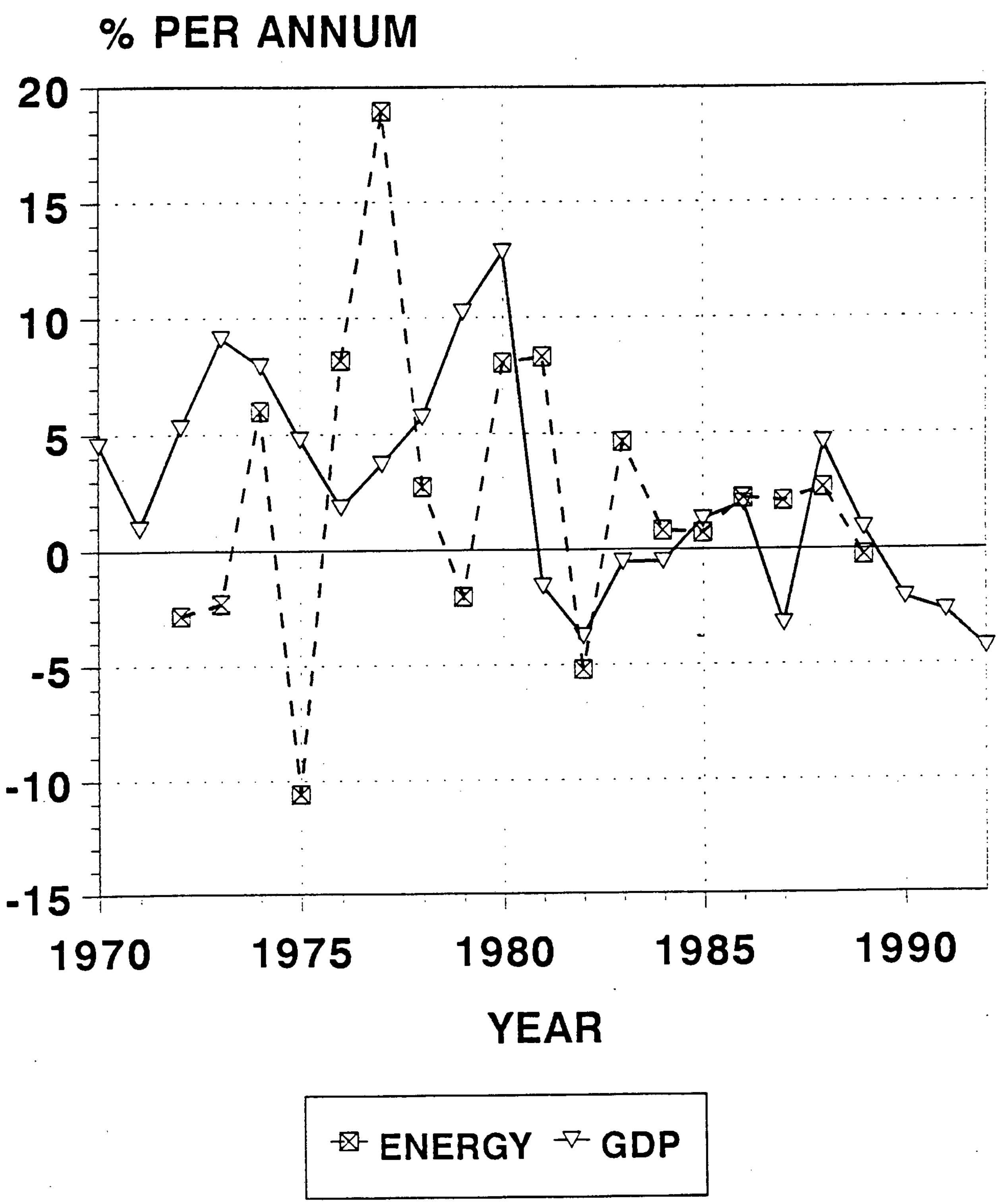

A 2.8

Figure 2.9 Agricultural sector GDP and energy growth rates



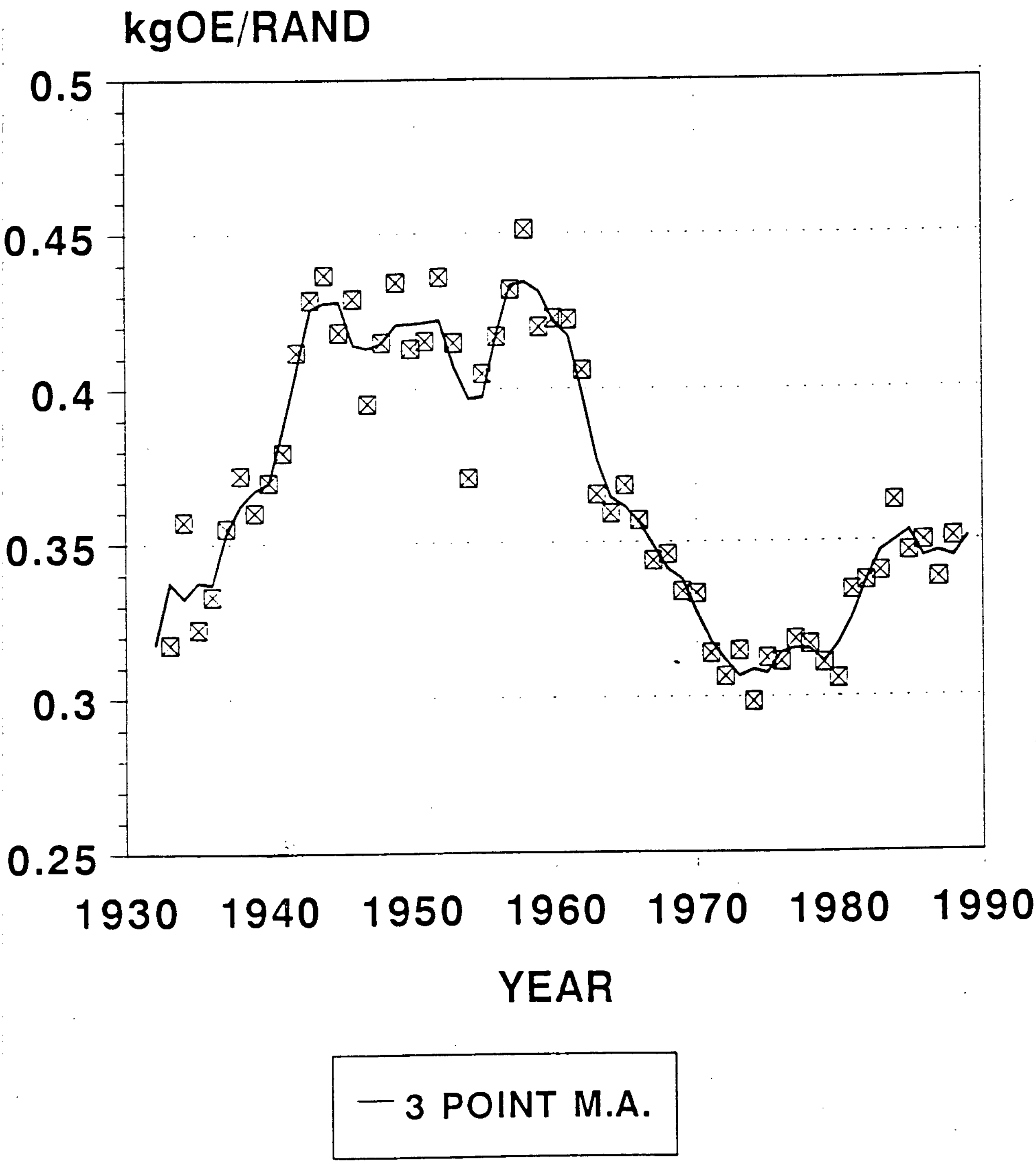

SA 2.9

Figure 2.10 Mining sector GDP and energy growth rates



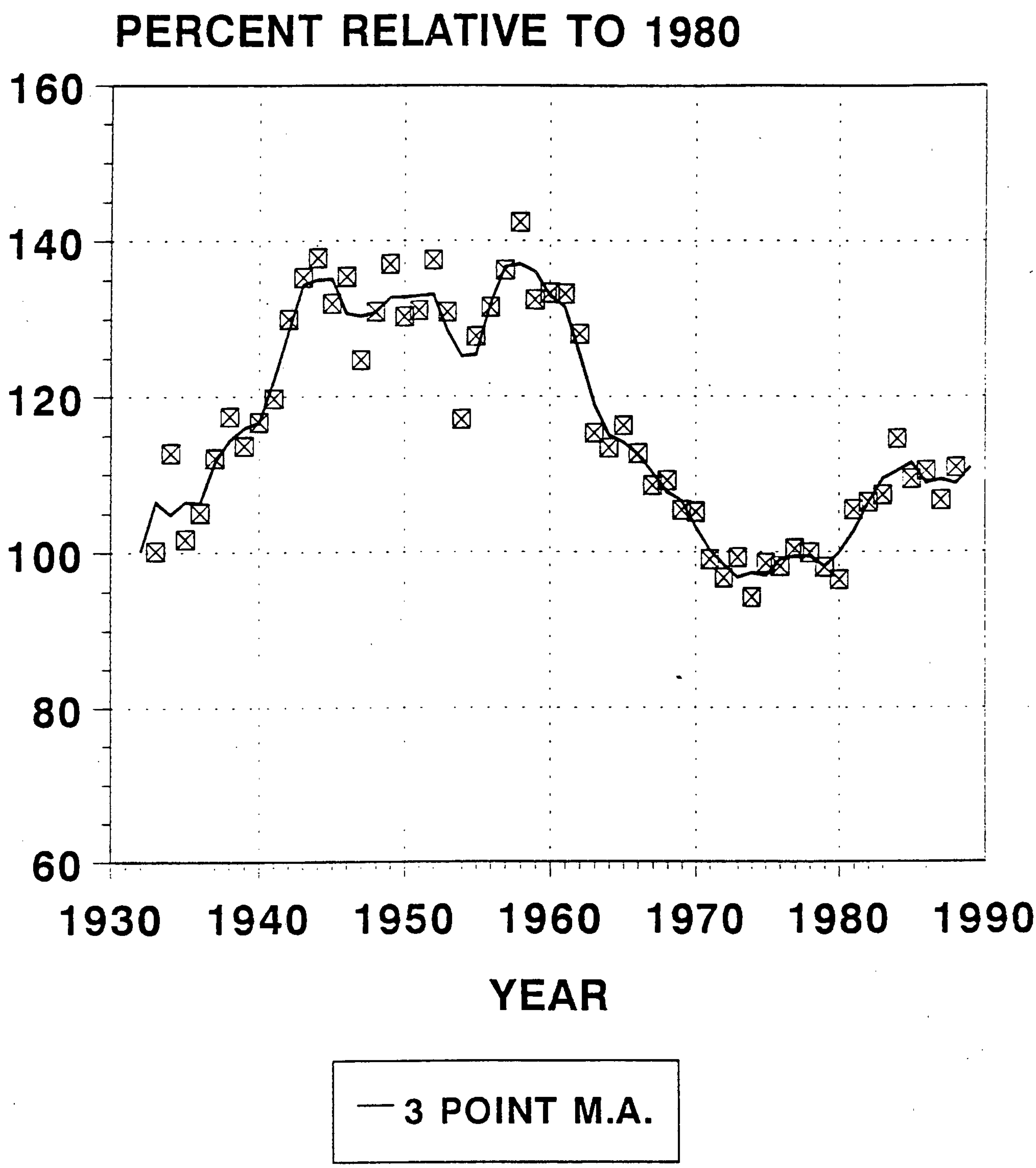

SA 2.10

Figure 2.11 Commercial energy intensity of total final consumption (1985 Rand)



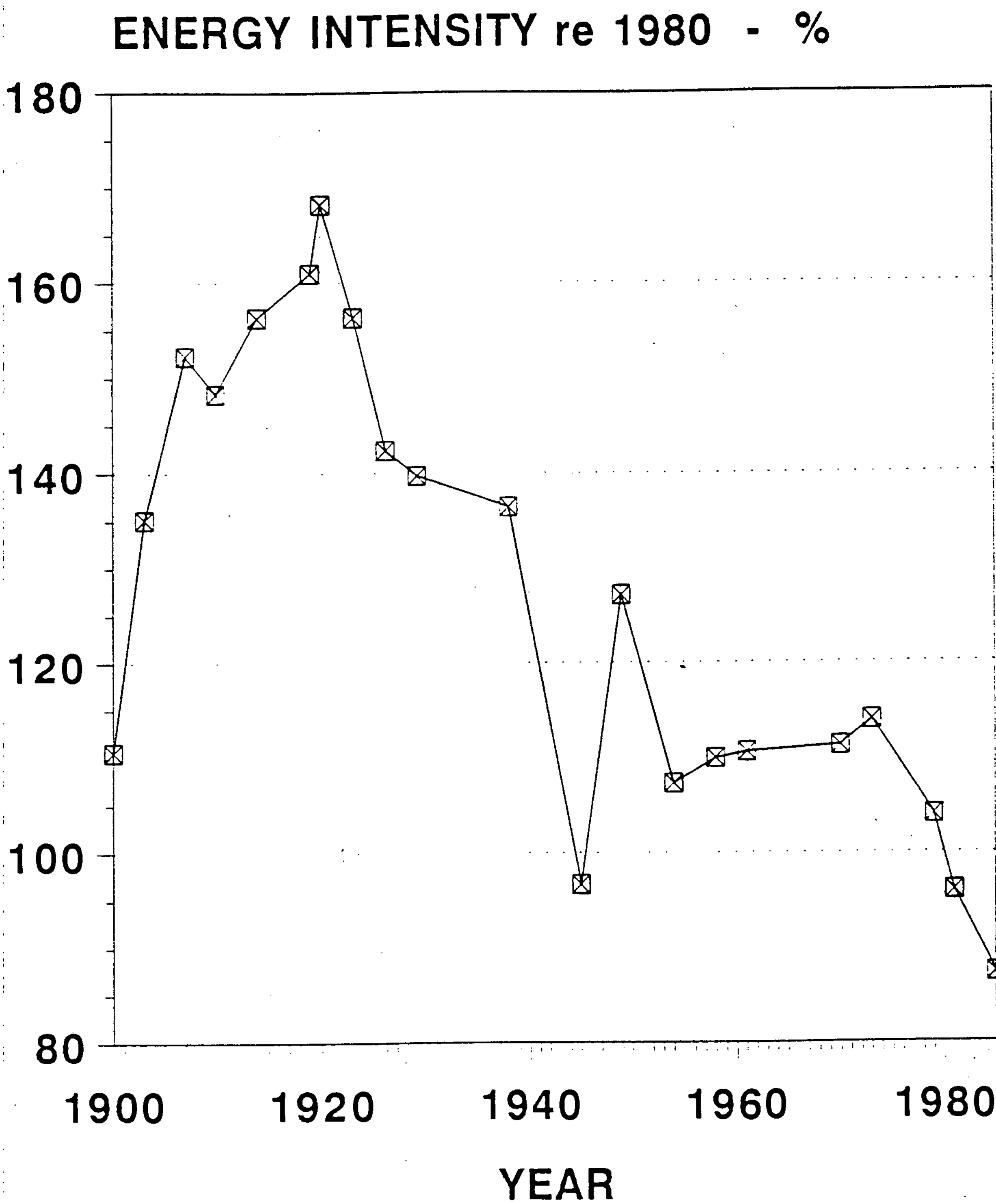

SA 2.11

Figure 2.12 Energy intensity in South Africa



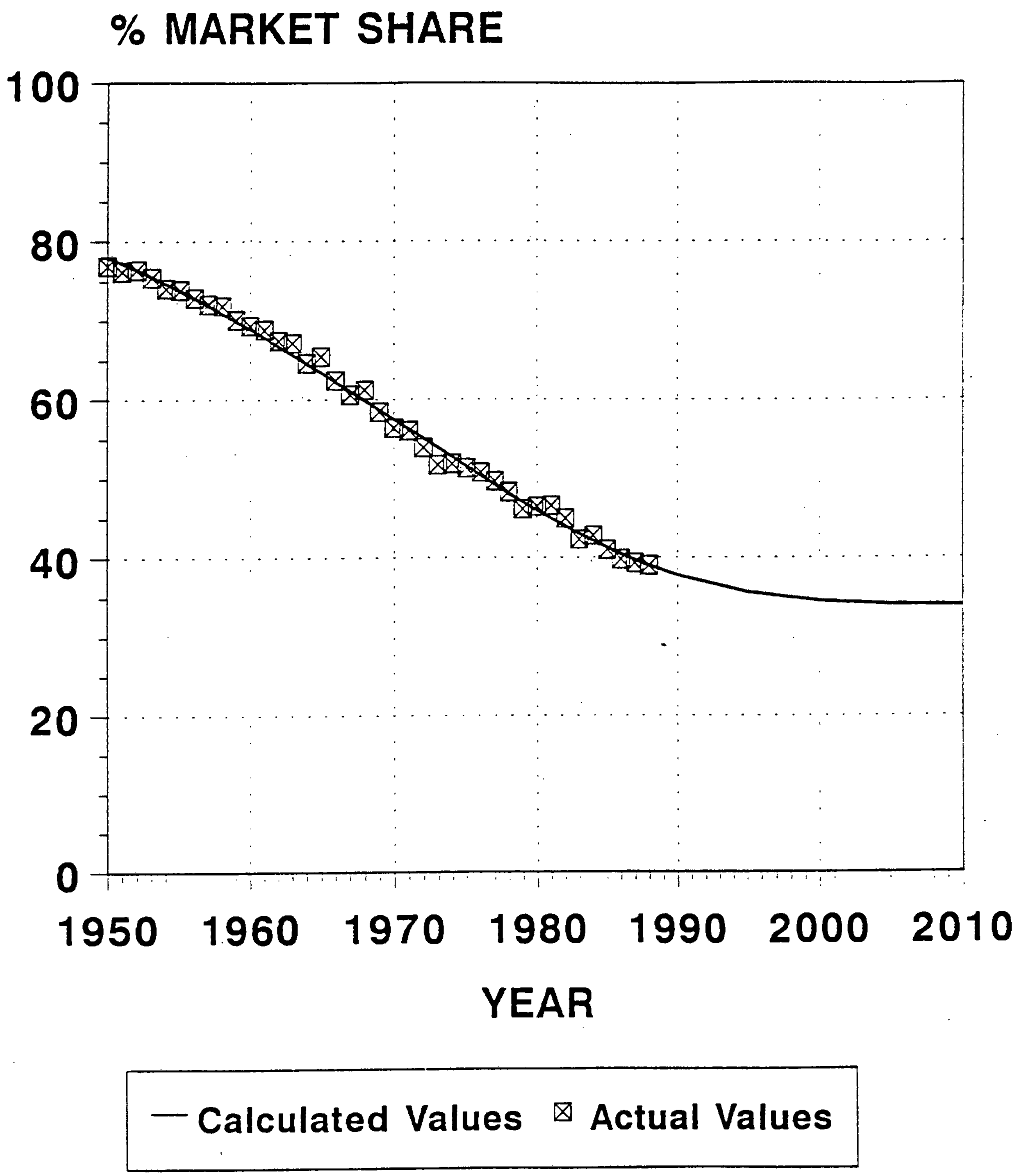

SA 2.12

Figure 2.13 Energy intensity in the USA



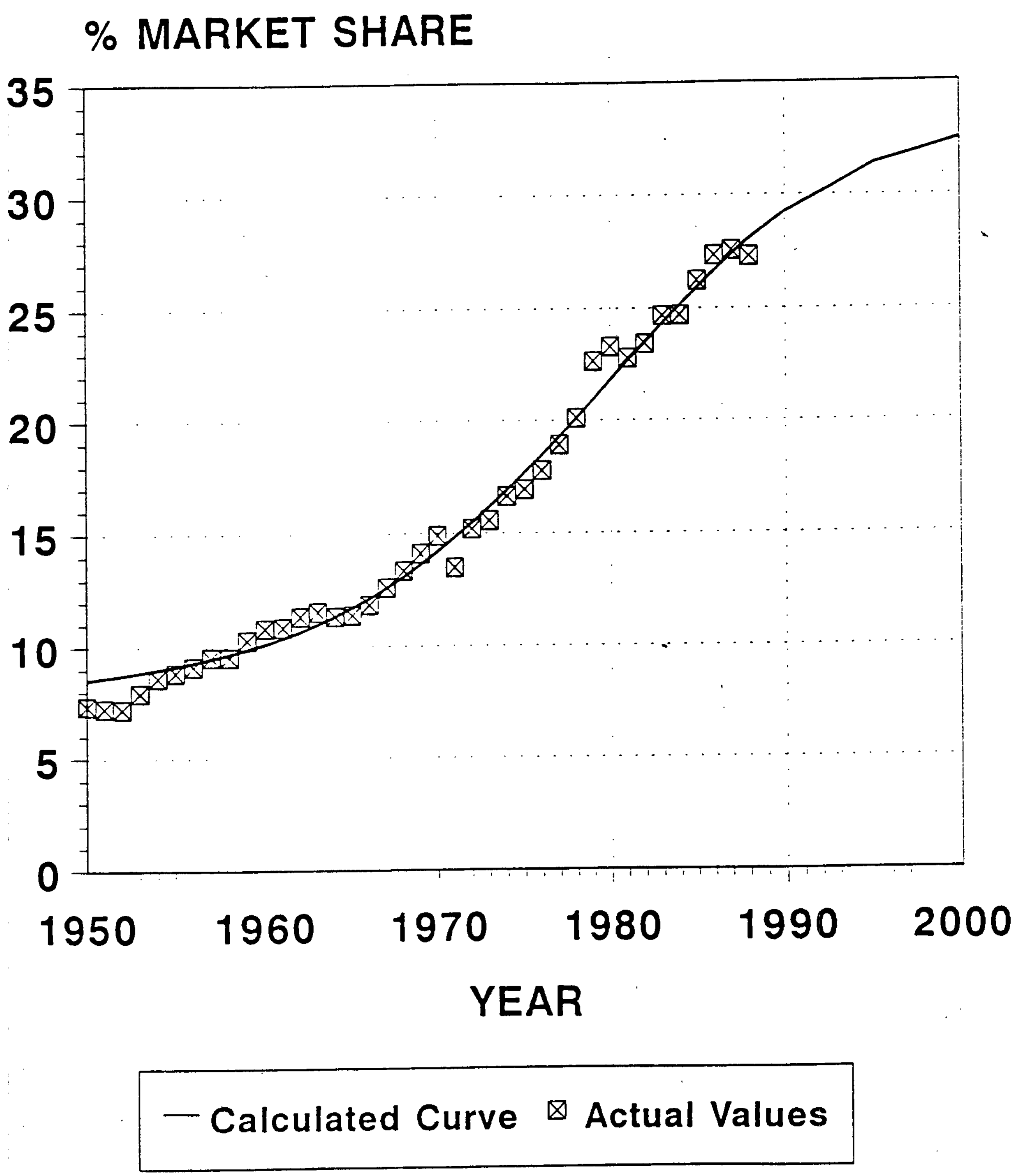

SA 2.13

Figure 2.14 Coal share of final energy consumption




SA 2.14

Figure 2.15 Electricity share of final energy consumption




SA 2.15

Figure 2.16 Oil share of final energy consumption

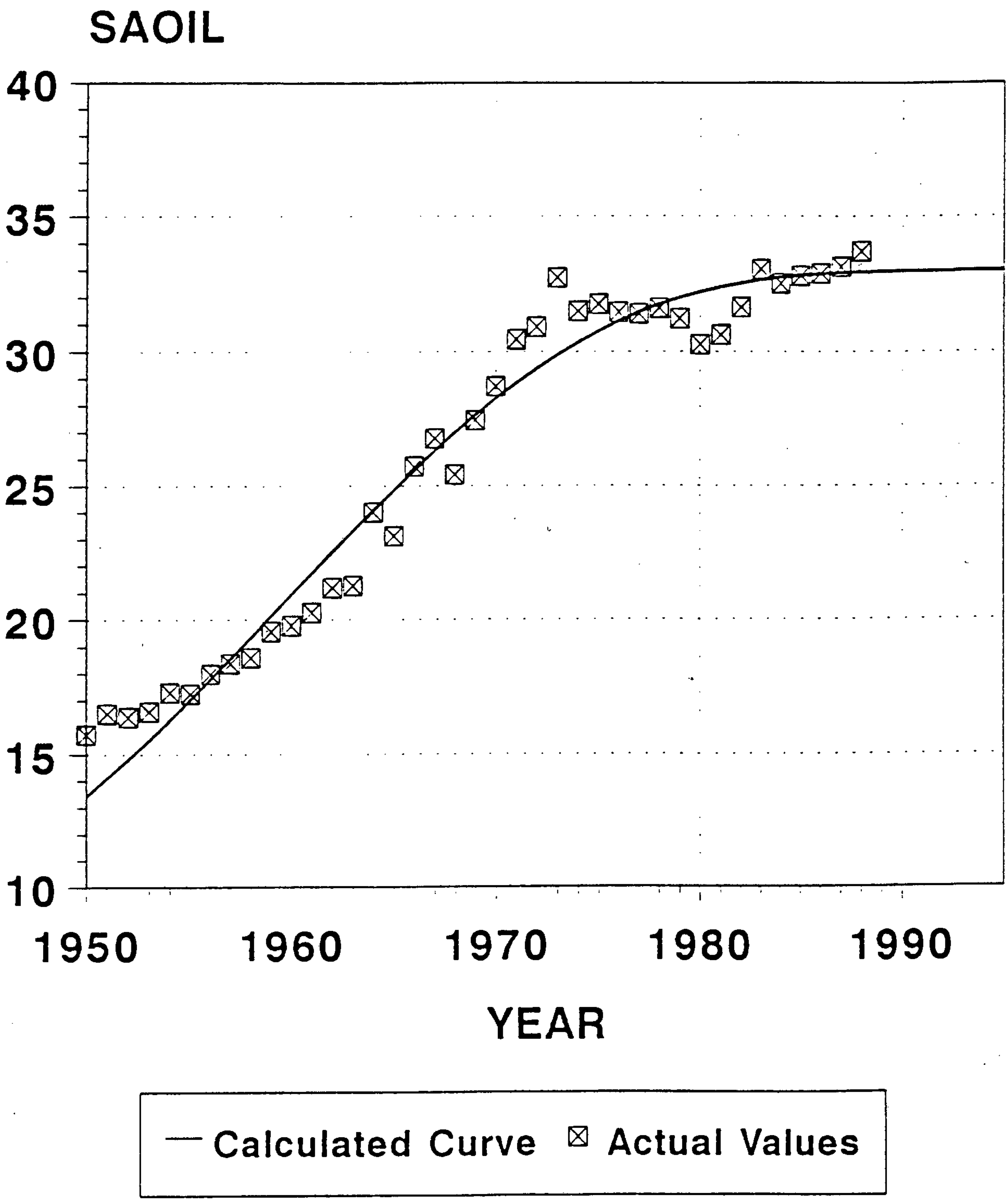



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Figure 2.17 Total final energy consumption

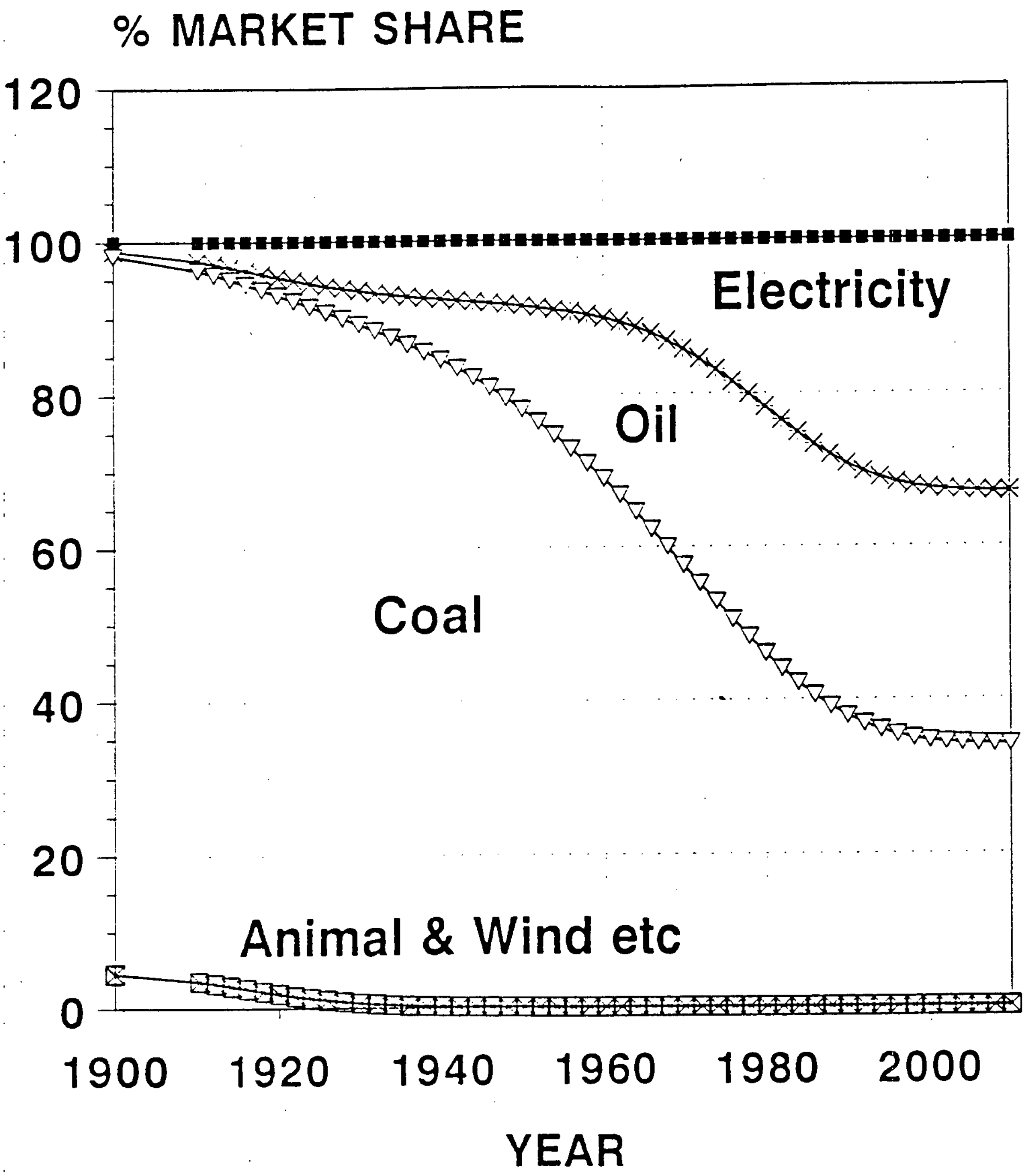


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Figure 2.18 Future energy intensity scenarios

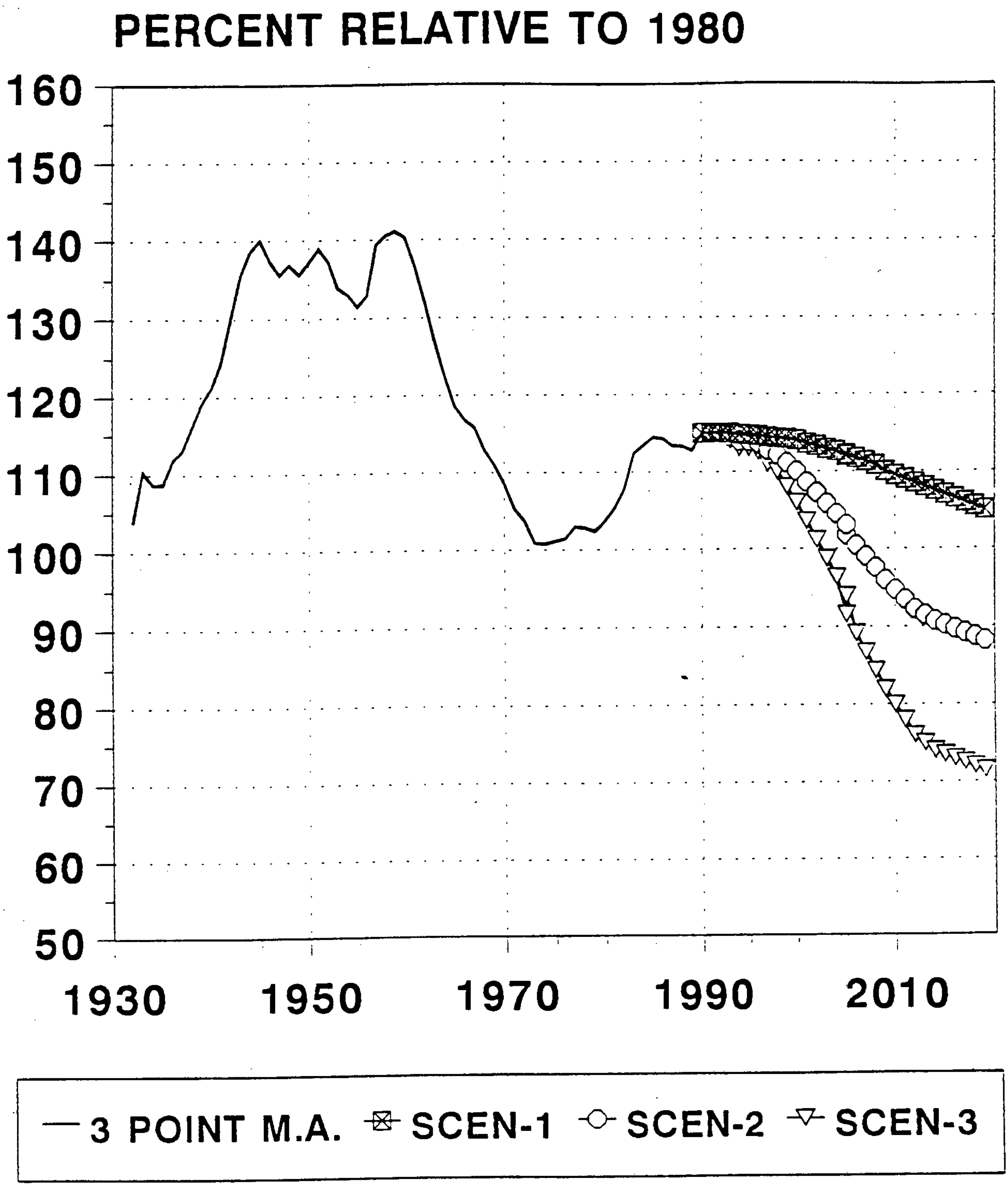


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Figure 2.19 Energy forecasts

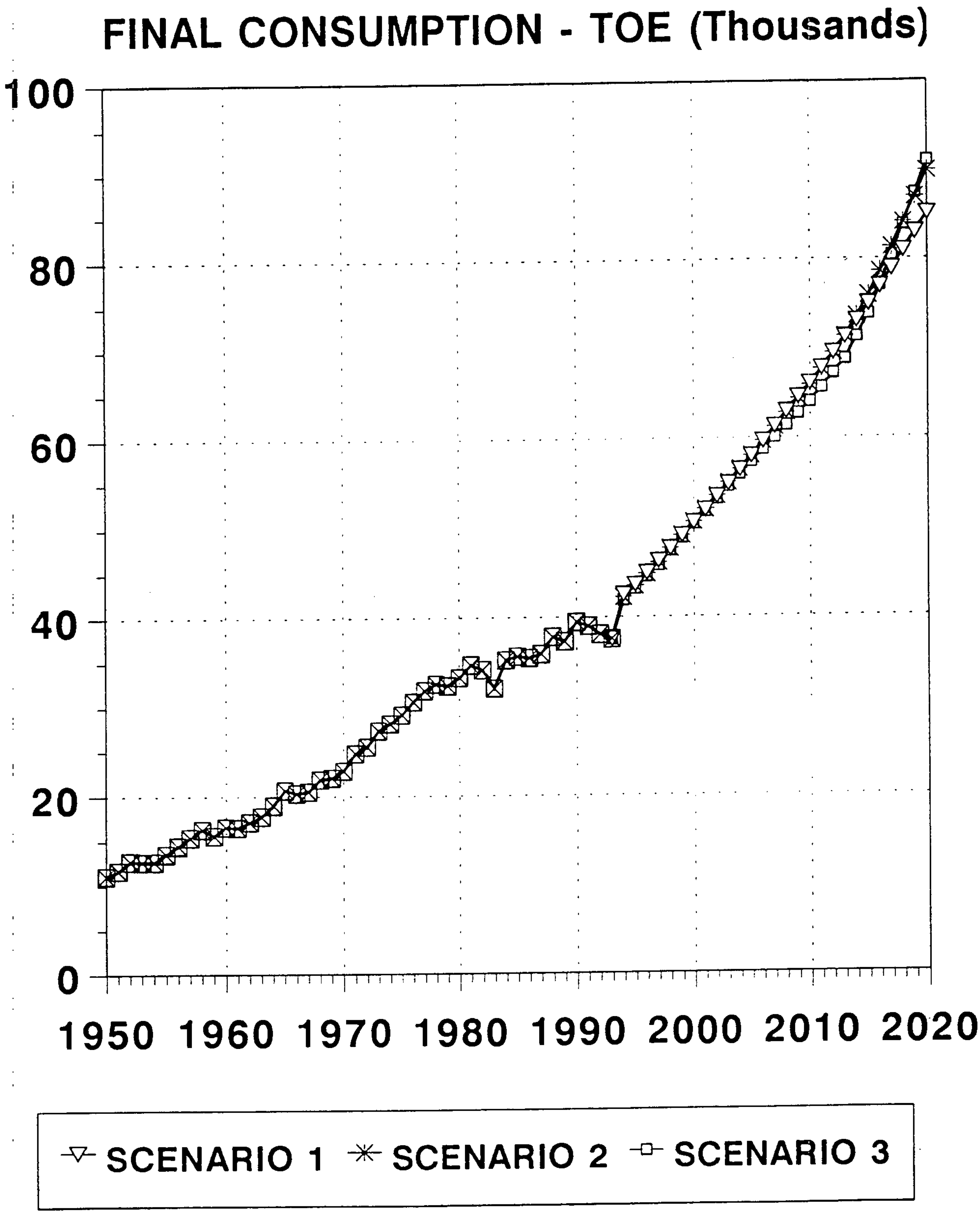


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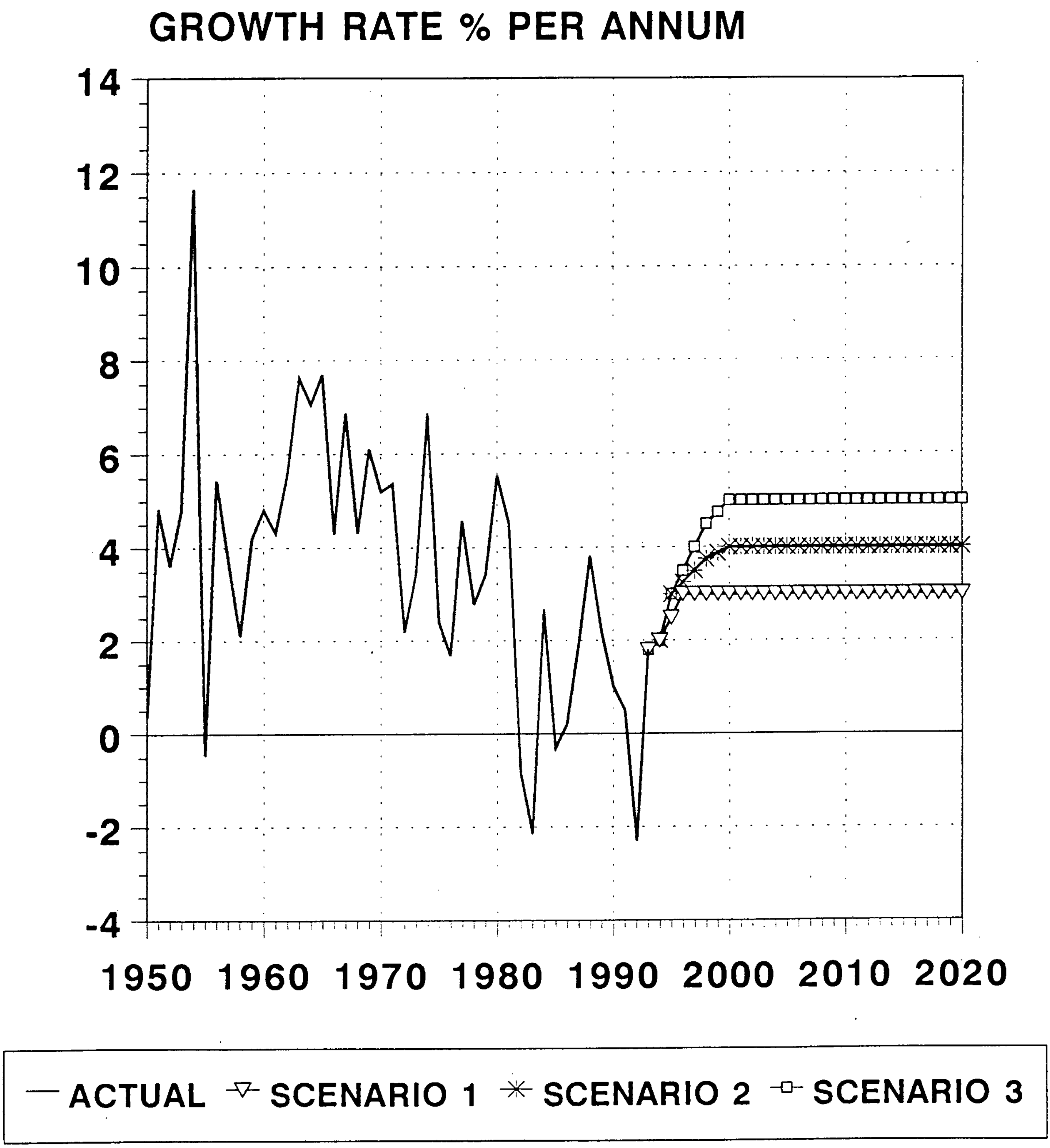
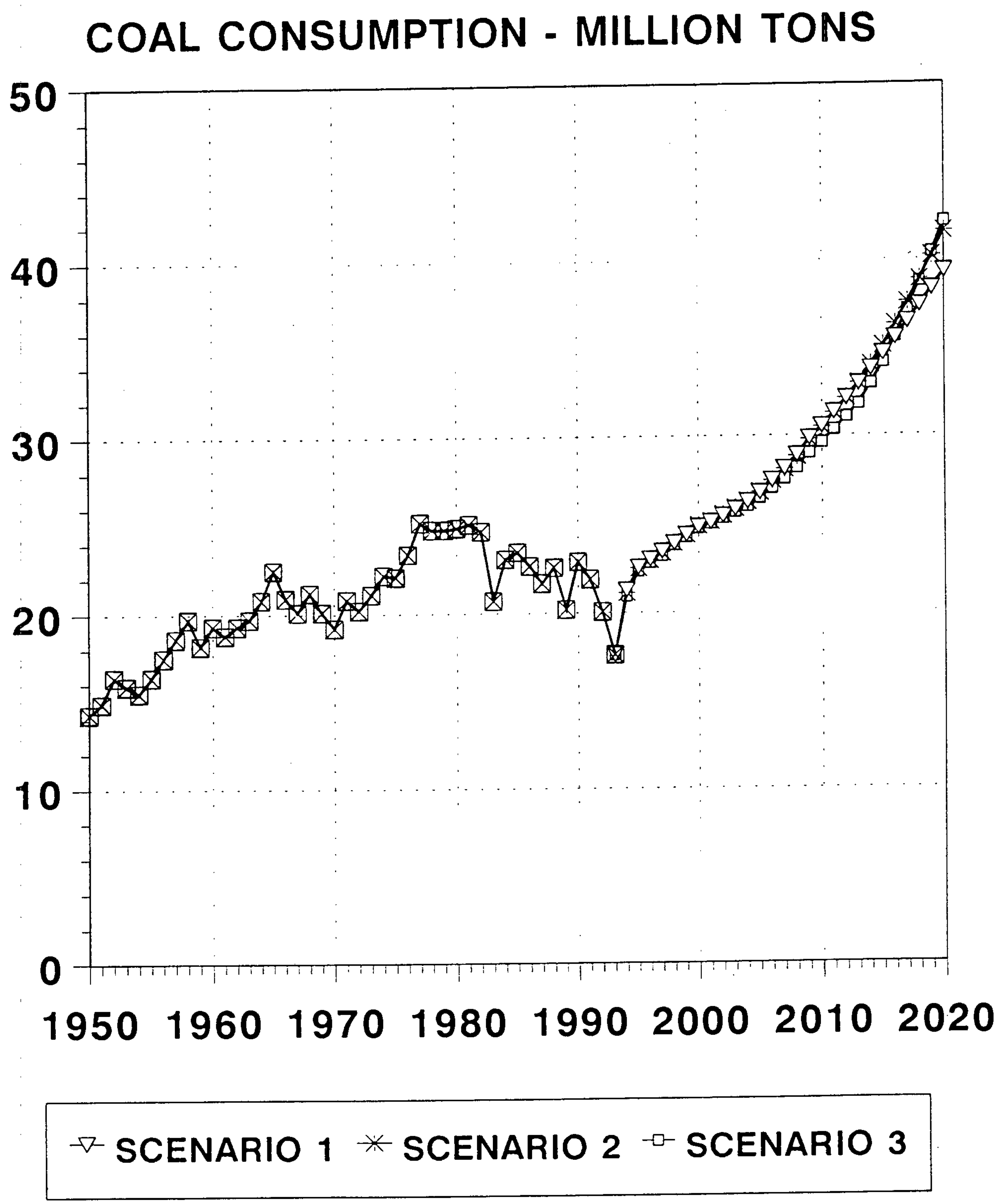
Figure 2.20 GDP growth rate - actual and forecast for the three scenarios



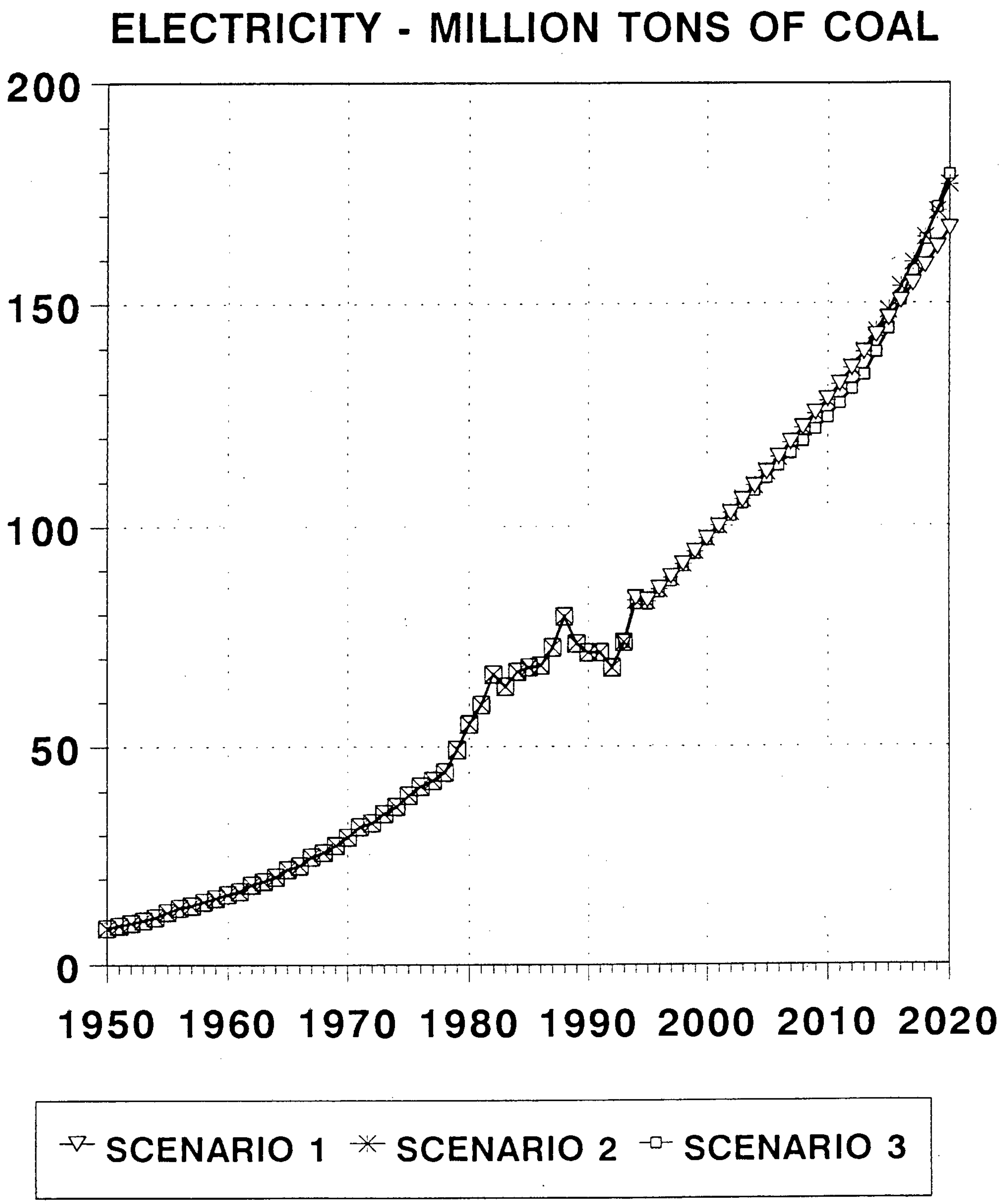

SA 2.20

Figure 3.1 Coal consumption in the final energy demand sector



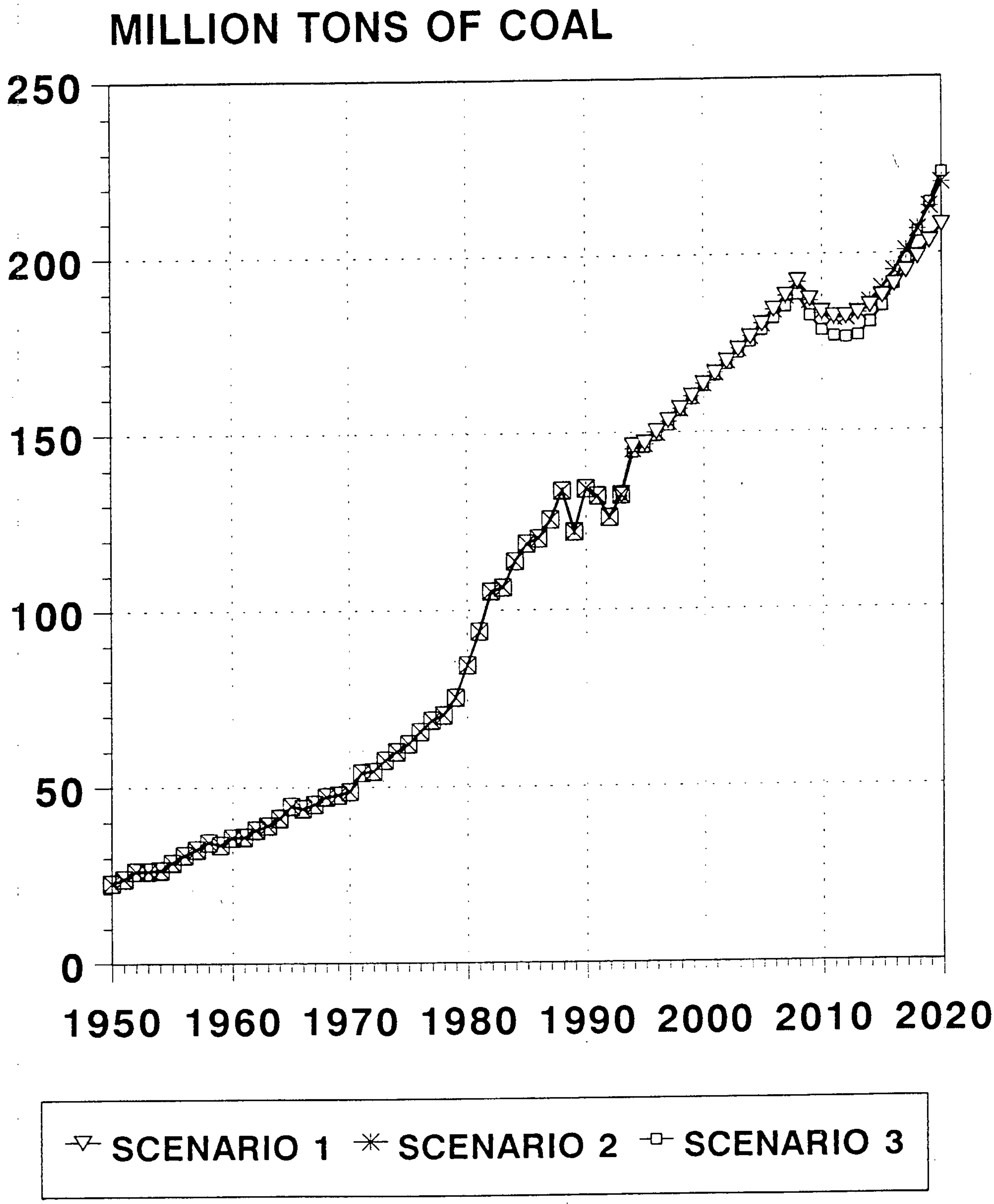

SA 3.1

Figure 3.2 Coal consumption for electricity generation



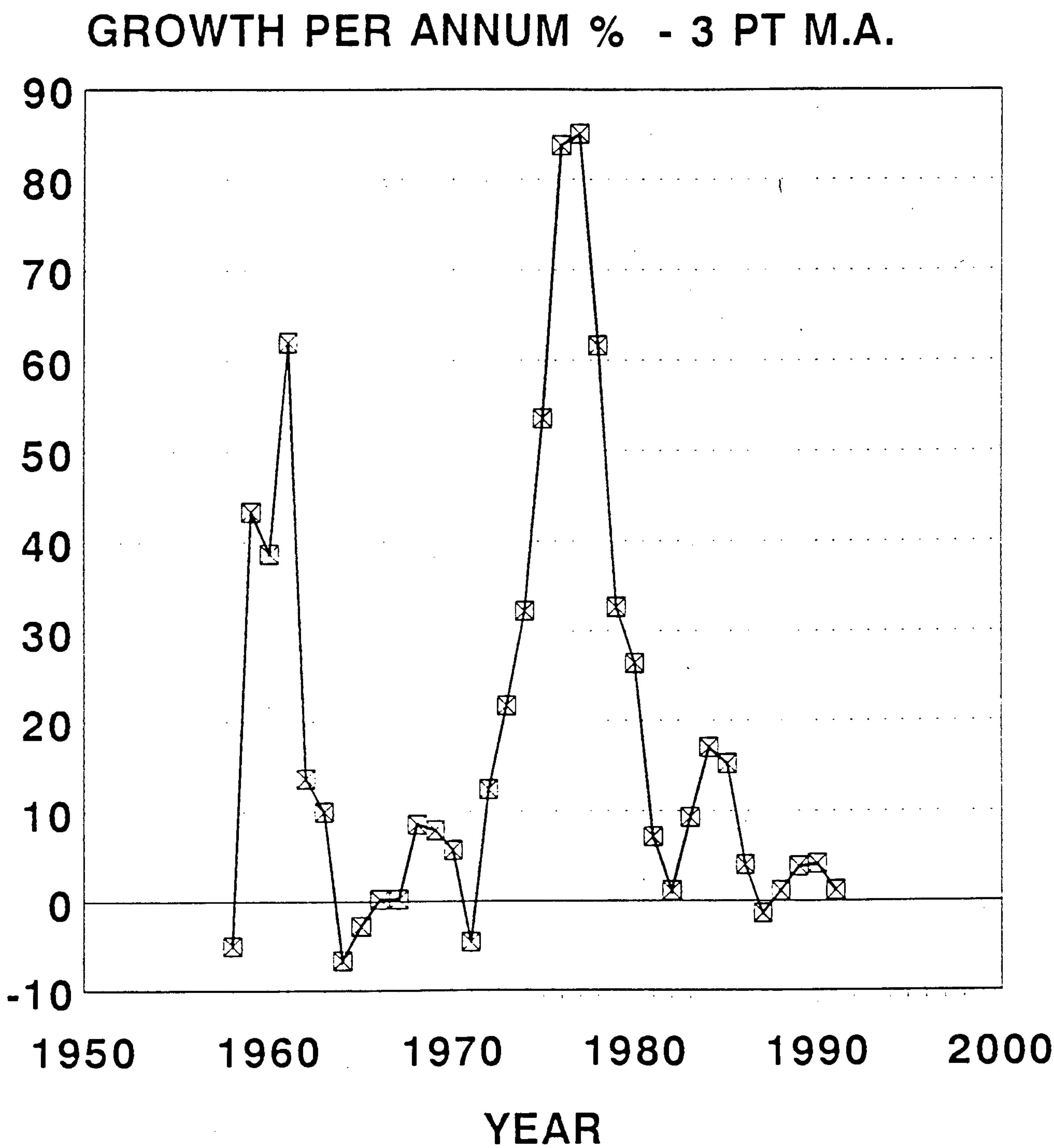

SA 3.2

Figure 3.3 Coal consumption for electricity, SASOL and final demand



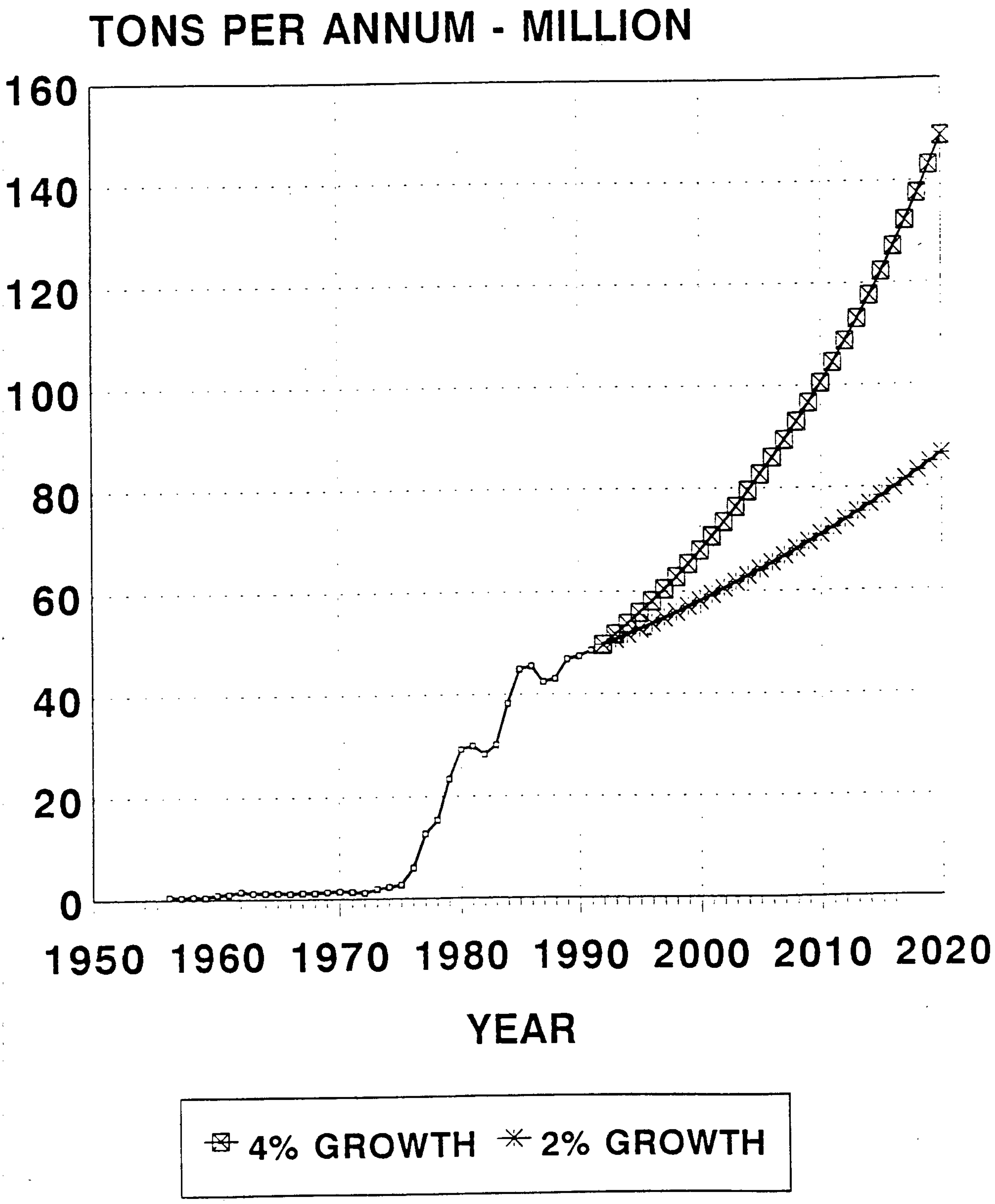

SA 3.3

Figure 3.4 Coal export - growth rate 1950 to 1990



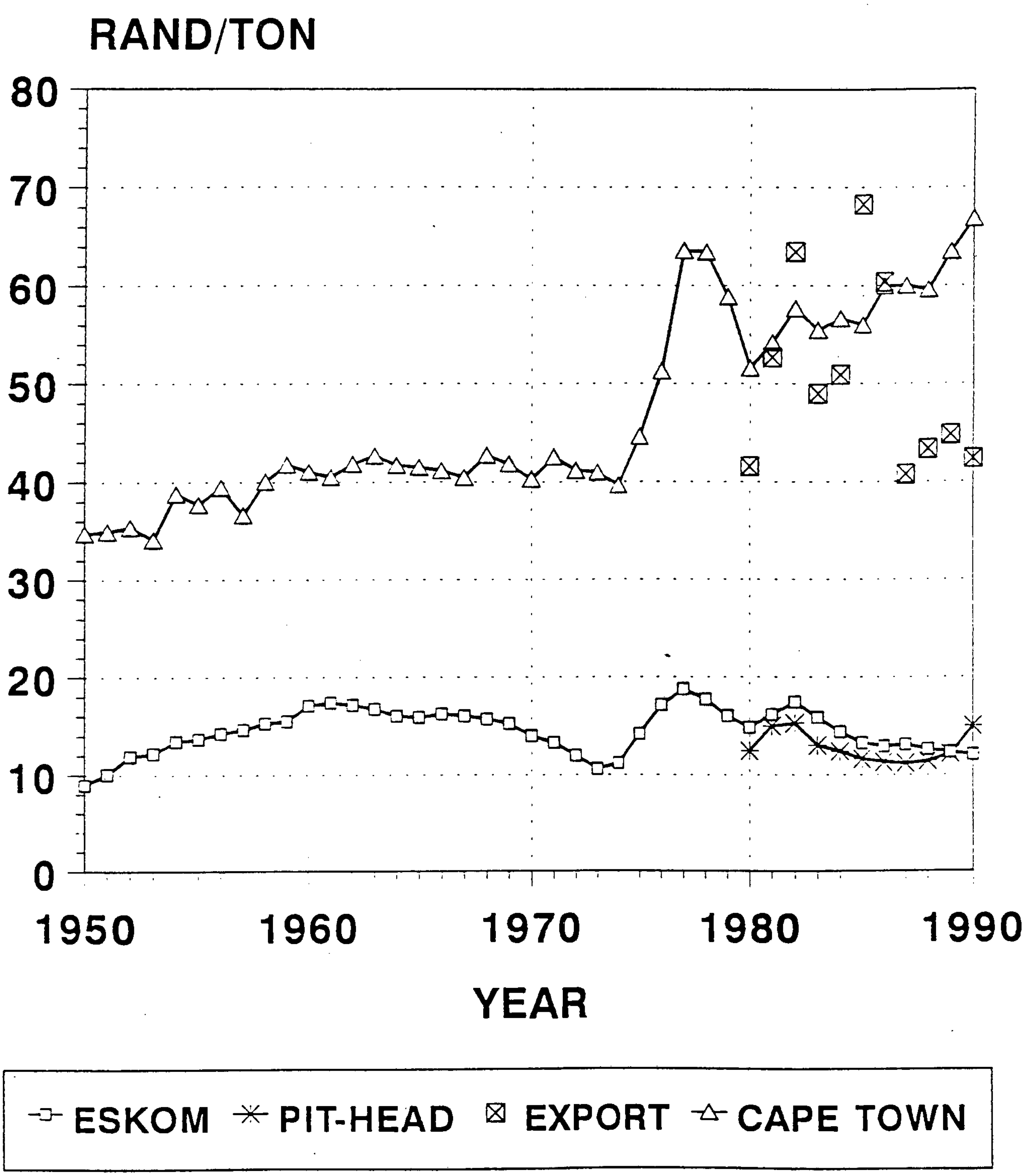

SA 3.4

Figure 3.5 Coal exports - actual and forecast to 2020



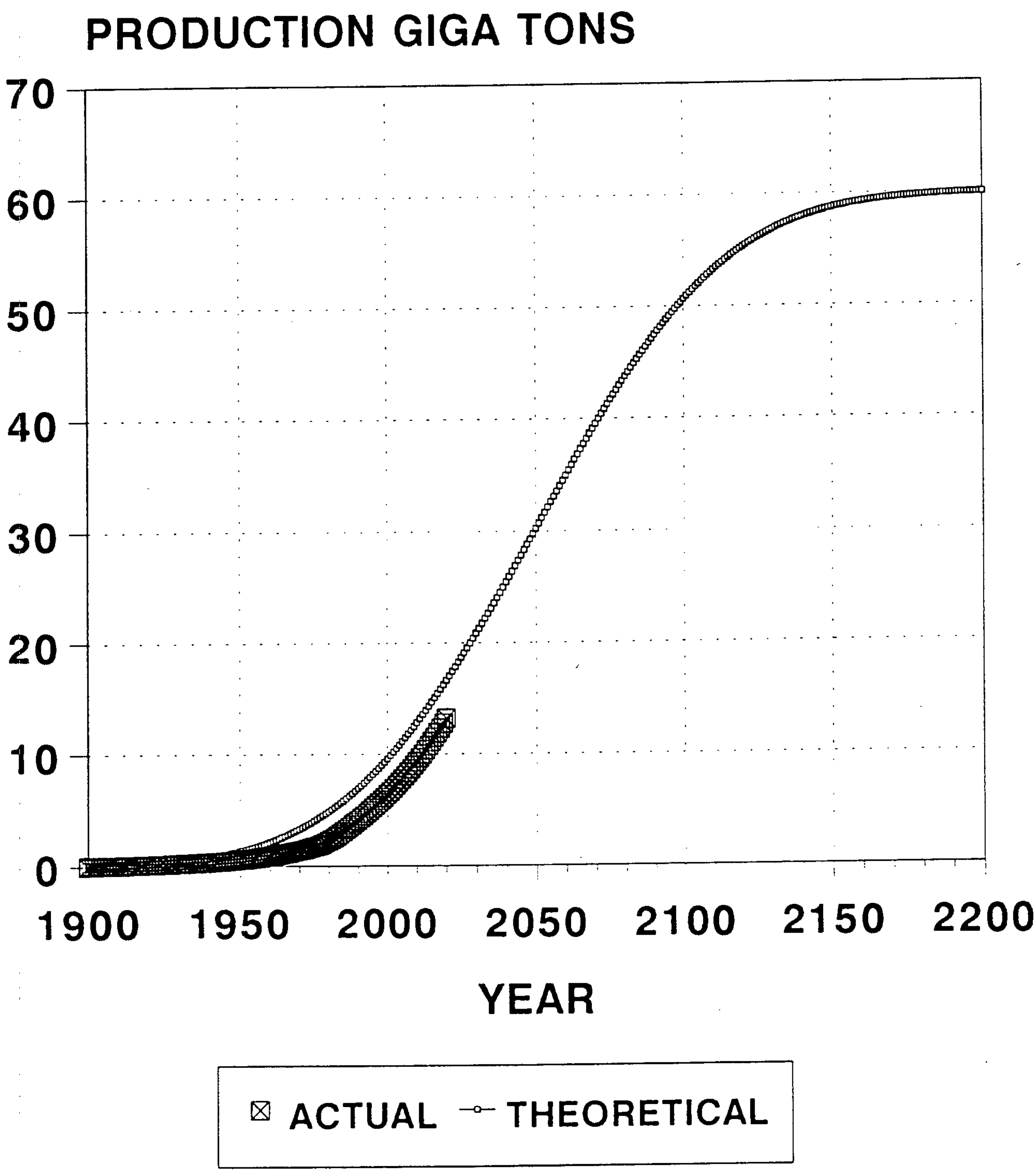

SA 3.5

Figure 3.6 Coal prices in South Africa (1985 Rand)



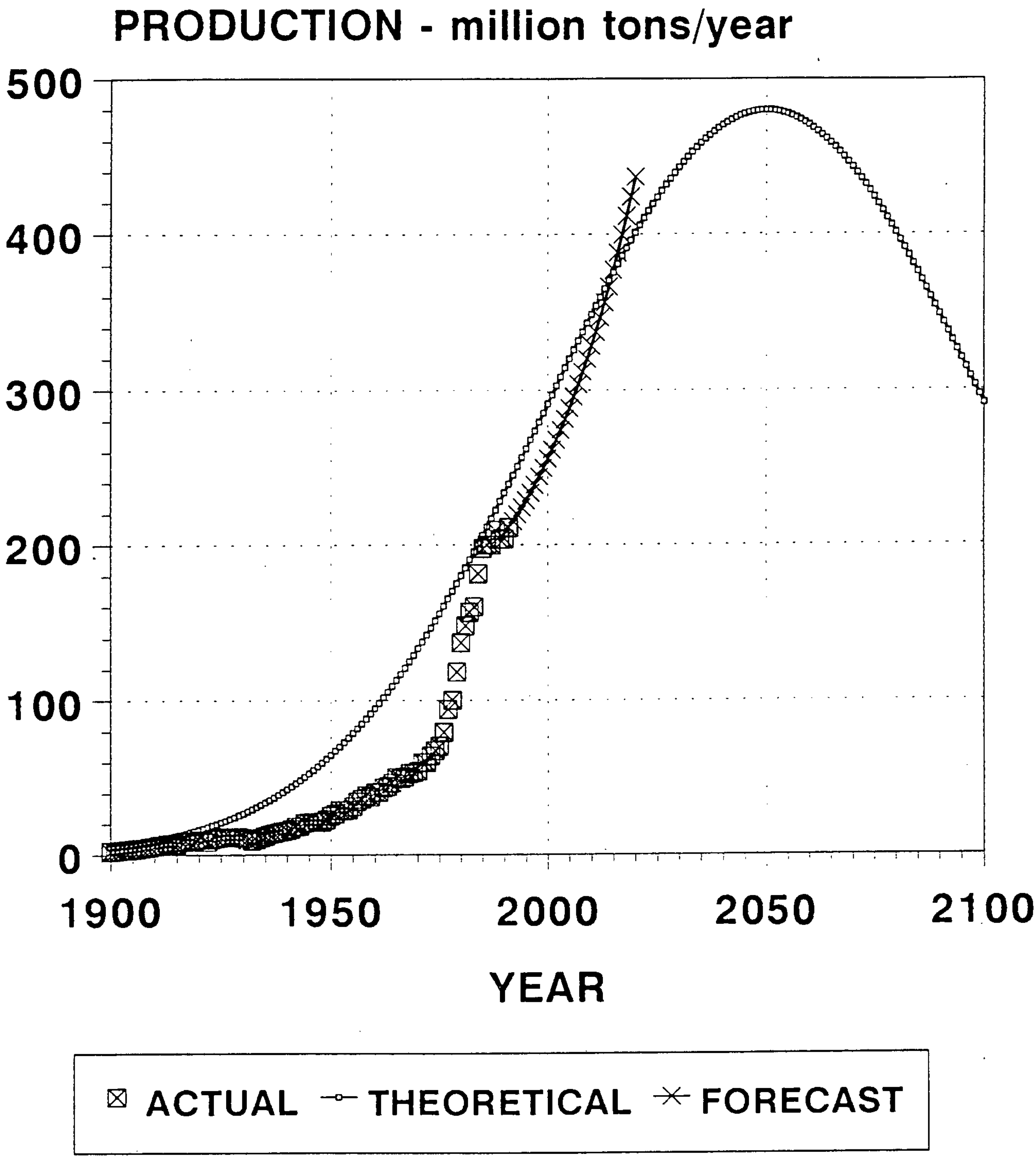

SA 3.6

Figure 3.7 Cumulative coal production - actual and theoretical (including discards)



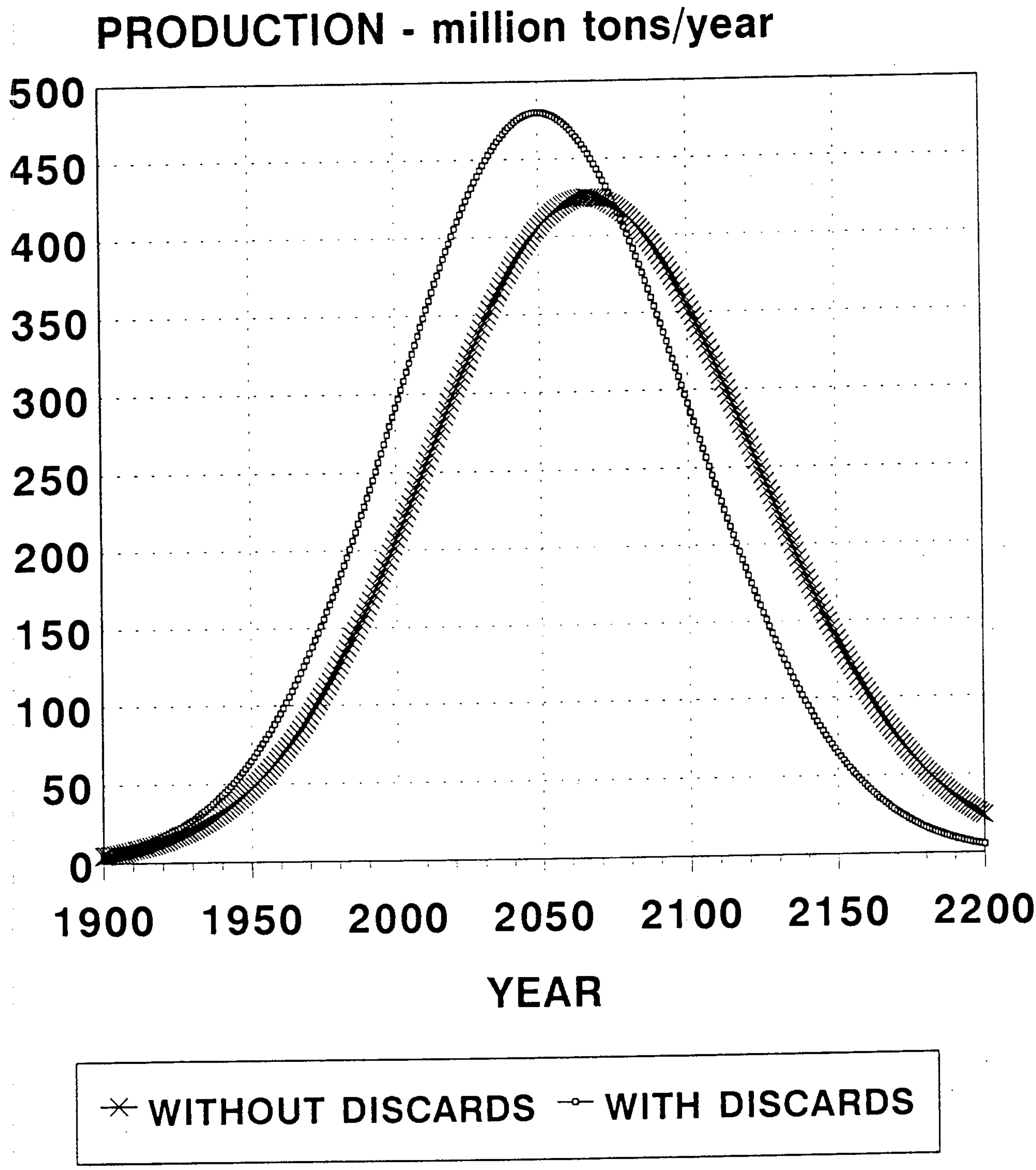

SA 3.7

Figure 3.8 Annual coal production - actual and theoretical (including discards)



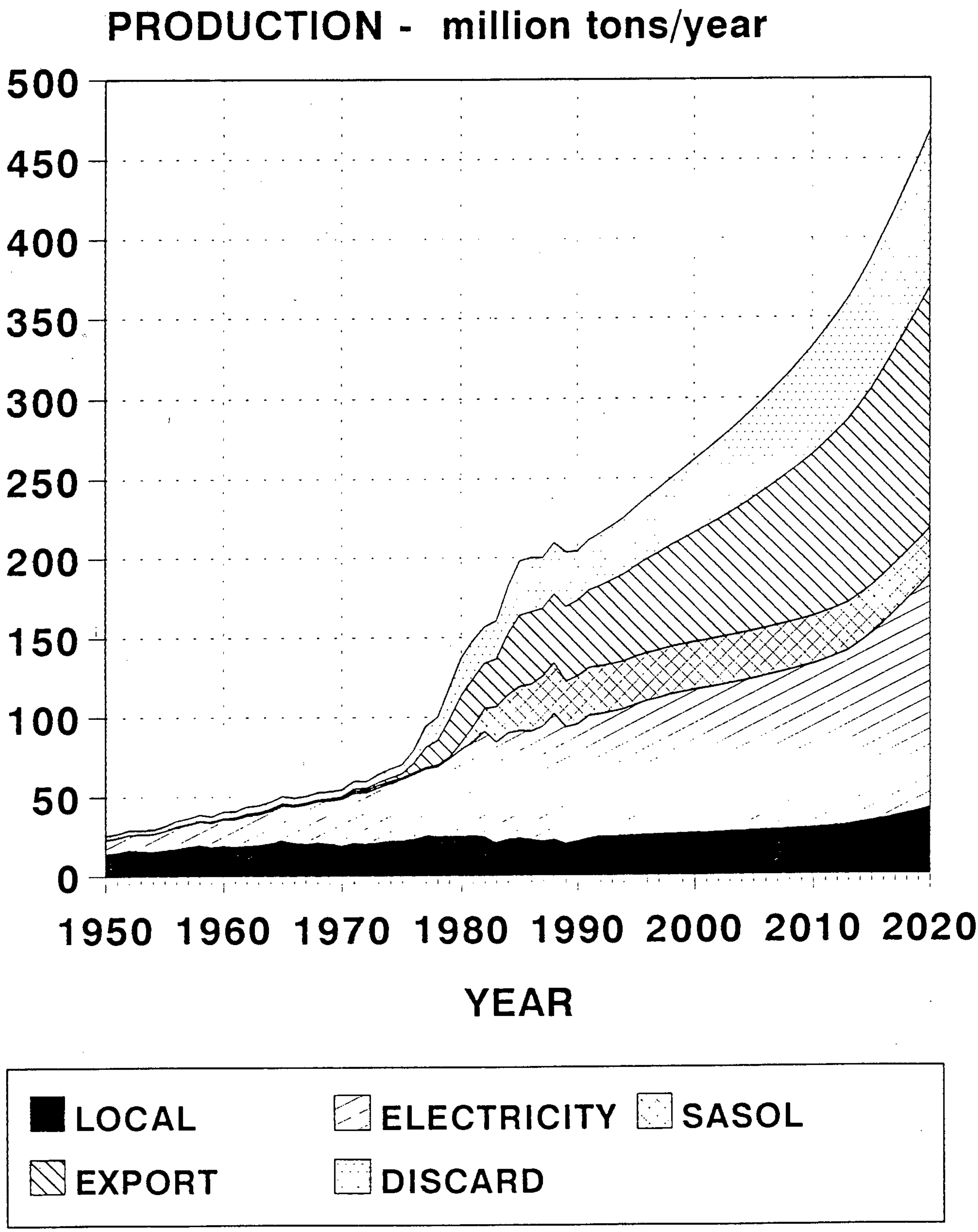

SA 3.8

Figure 3.9 Comparison of theoretical coal requirements with and without discard coal




SA 3.9

Figure 3.10 Coal consumption scenario




SA 3.10

Figure 4.1 ESKOM maximum turbine set size

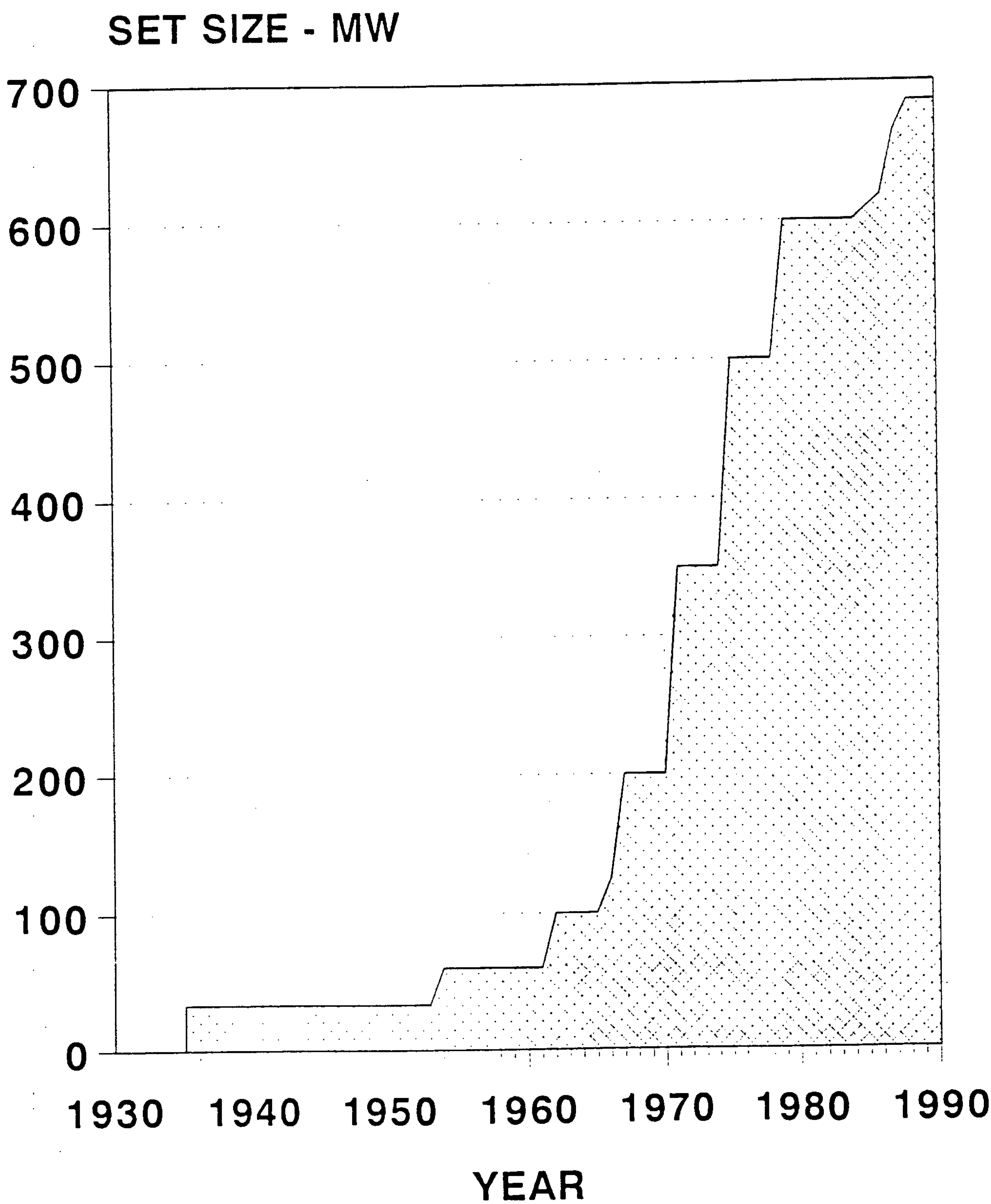


Figure 4.2 Installed capacity and maximum demand on the ESKOM system

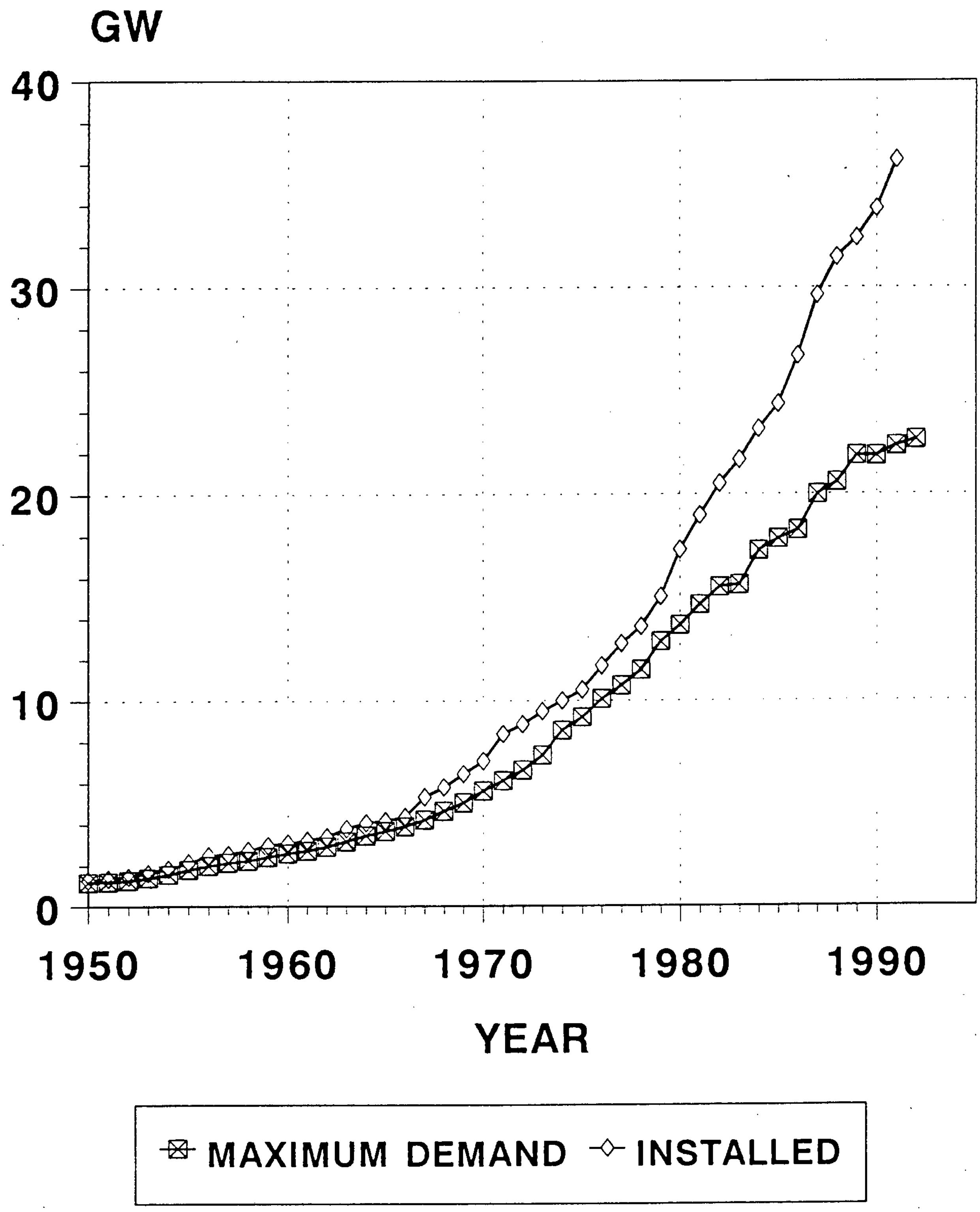



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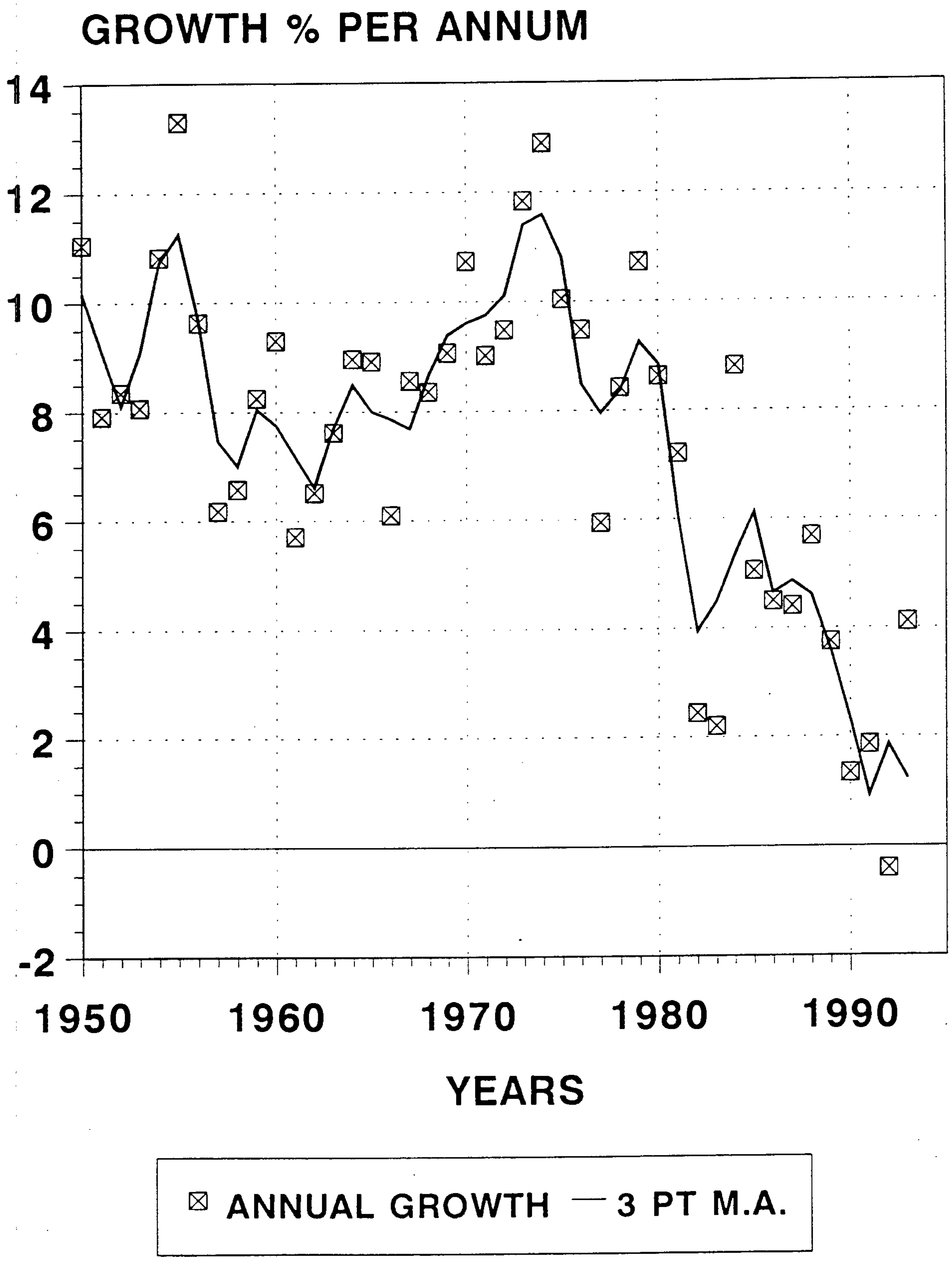
Figure 4.3 Annual growth rate in units sold on the ESKOM system




SA 4.3

Figure 4.4 Reserve capacity as a percentage of installed capacity

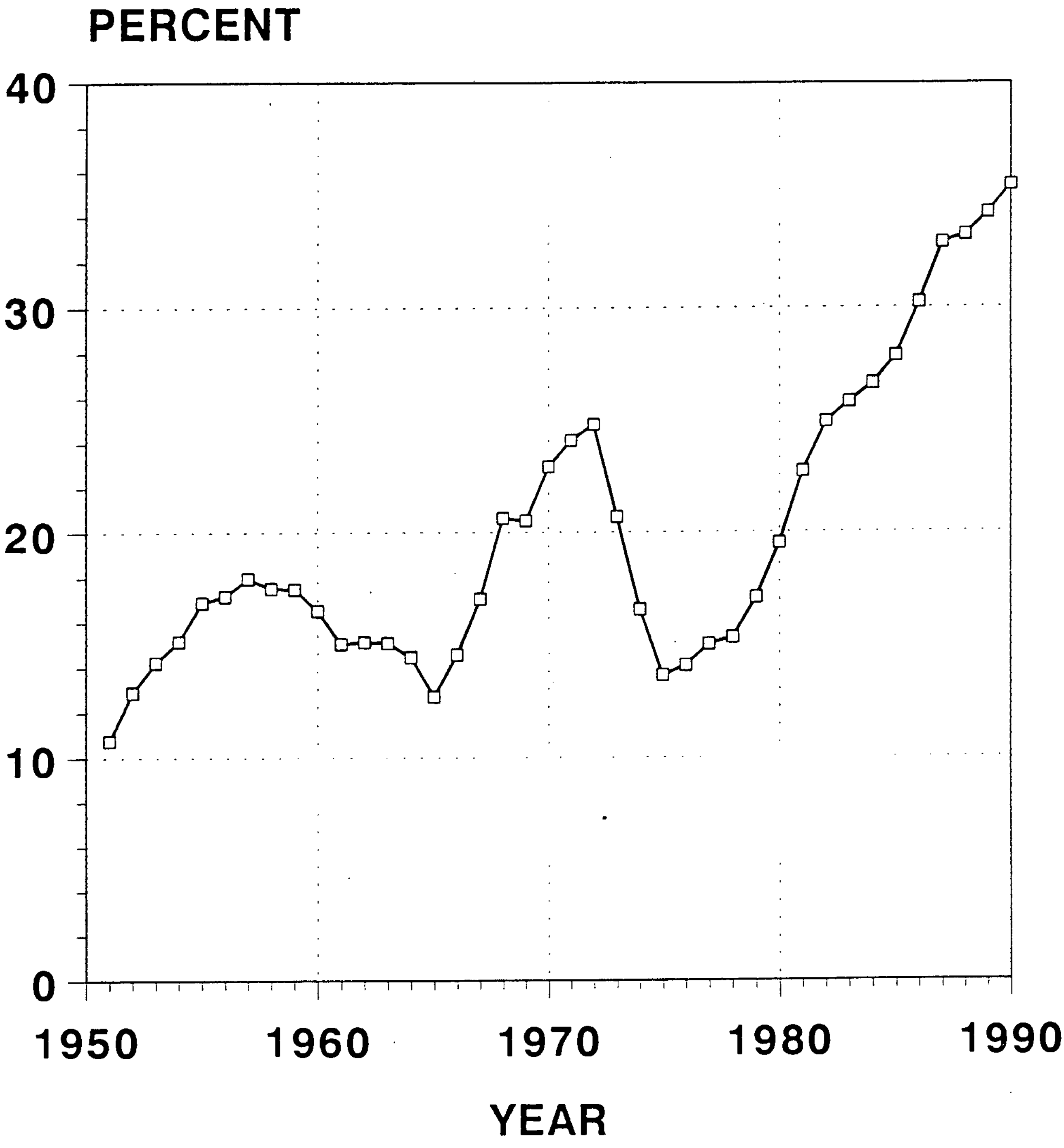



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Figure 4.5 ESKOM price of electricity and the operating cost of coal per unit of electricity sold (1985 Rand)

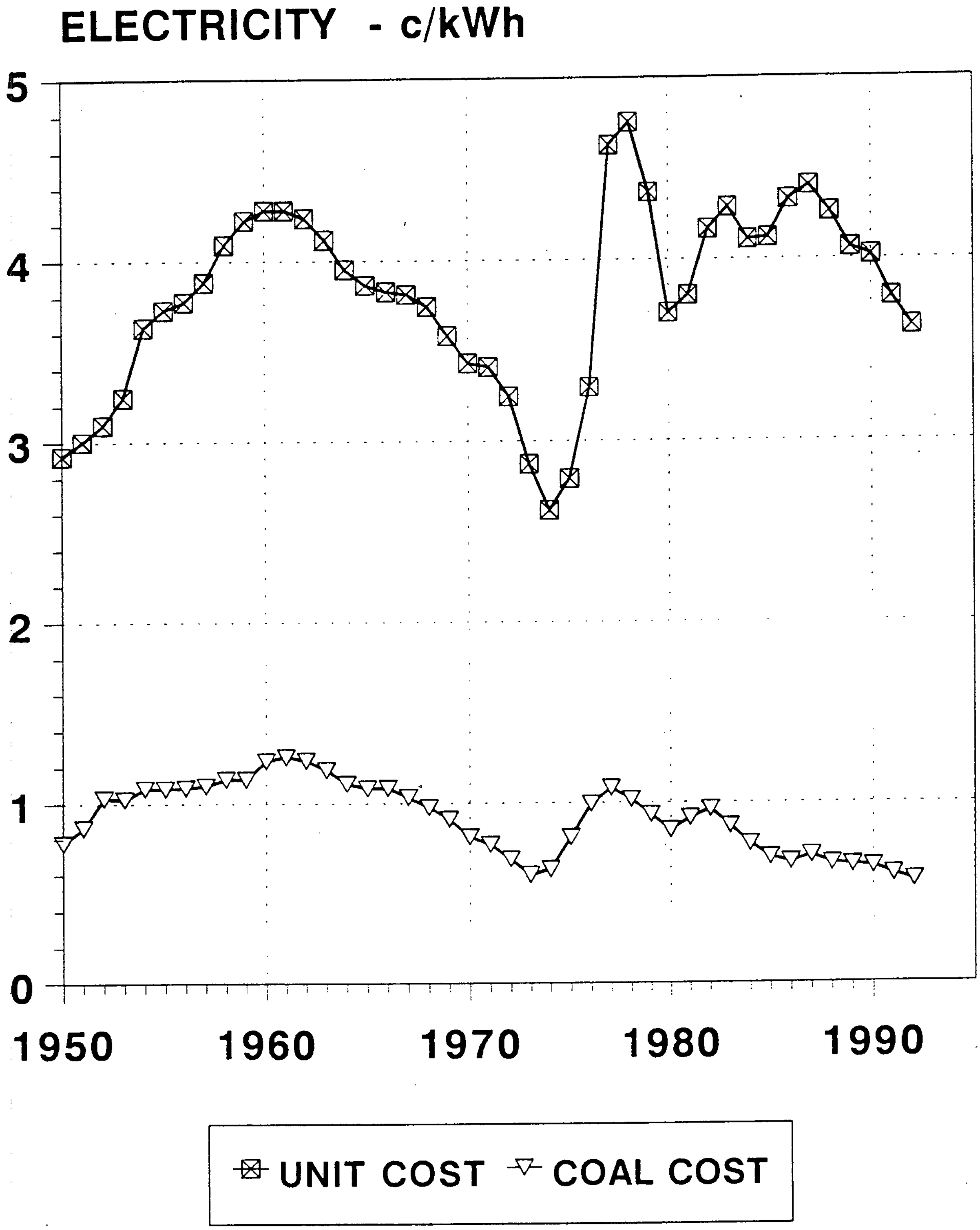


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Figure 4.6 Coal cost as a percentage of the price of electricity

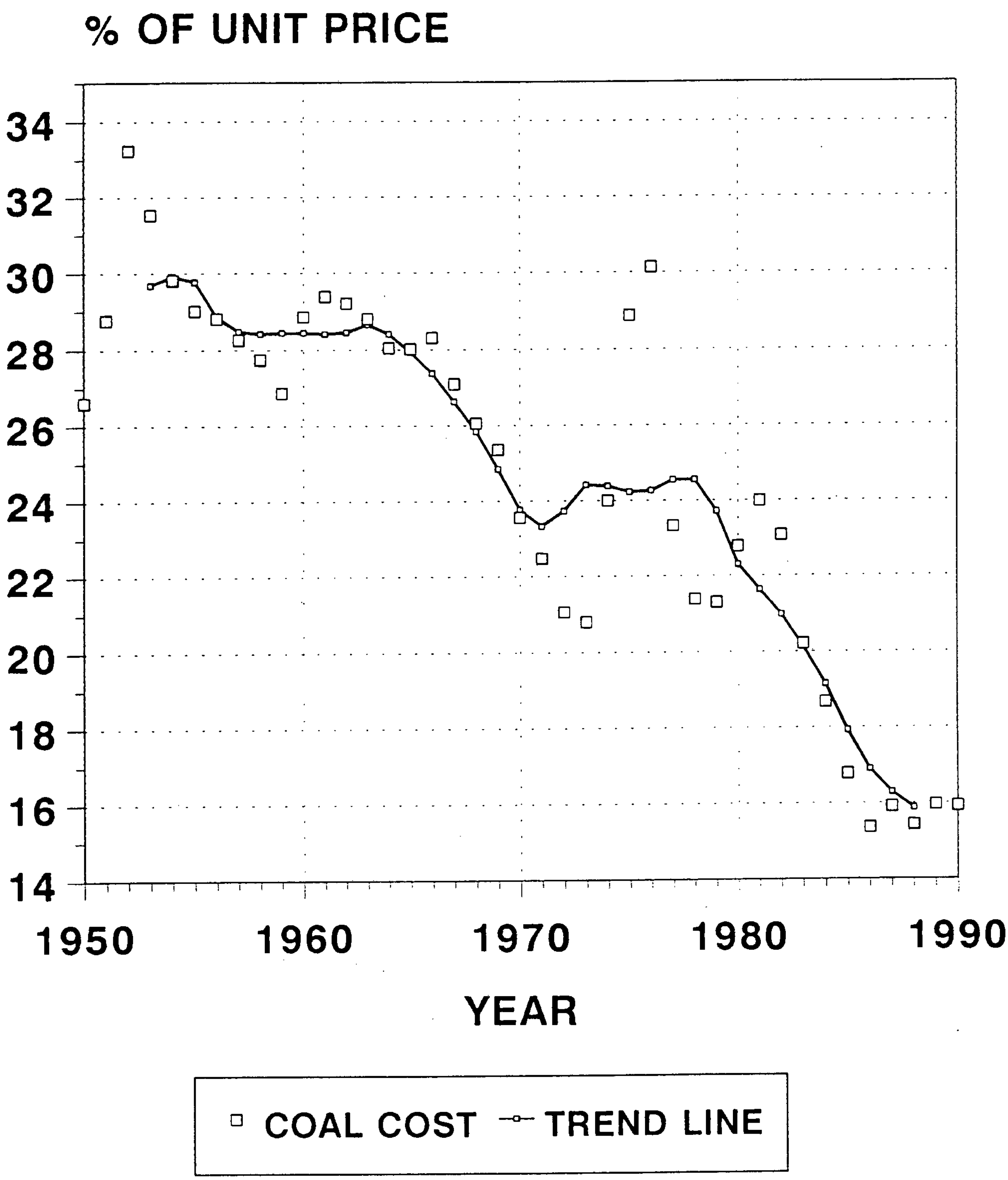


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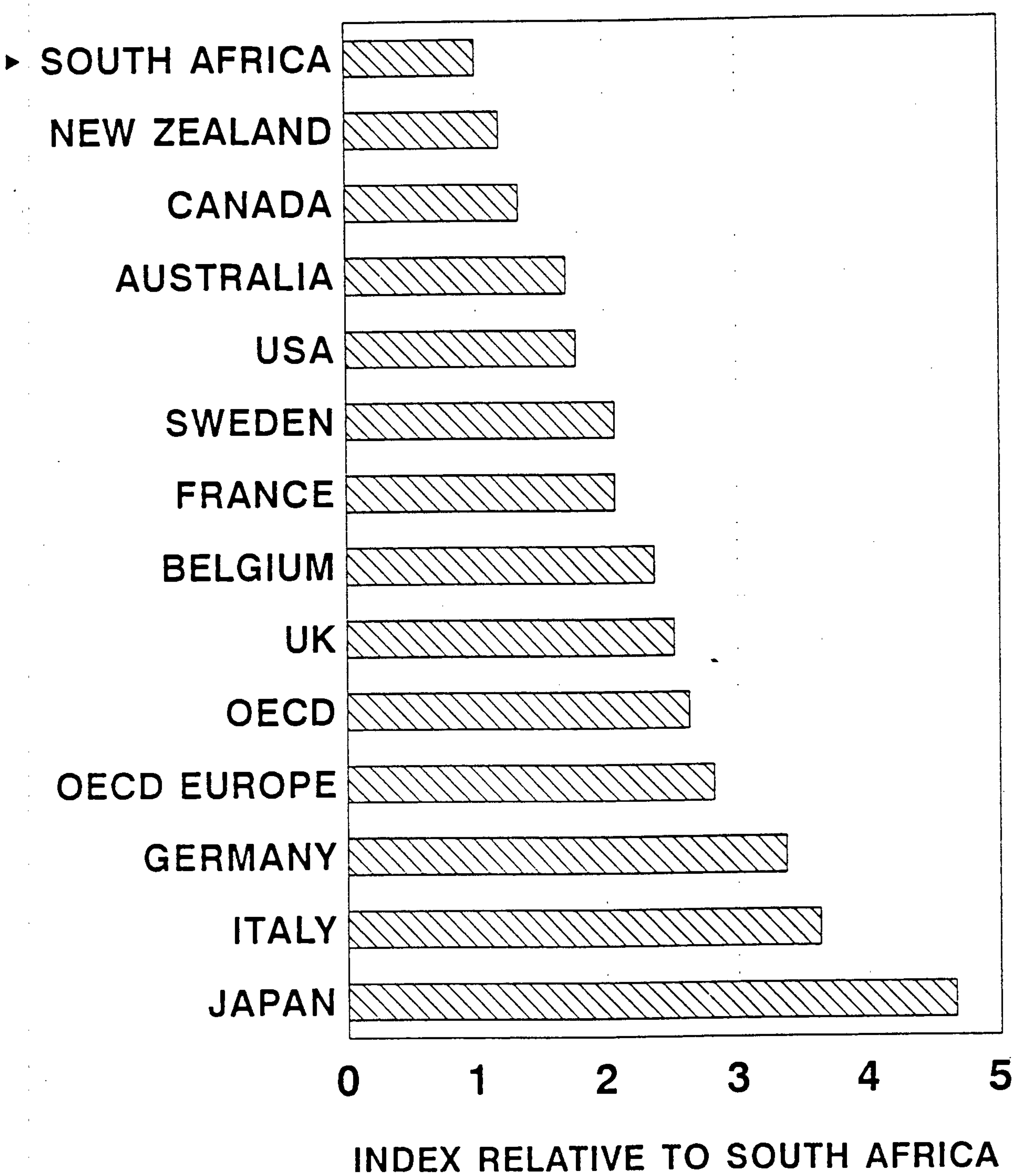
Figure 4.7 International comparison of electricity prices to industrial consumers




SA 4.7

Figure 4.8 Electricity sales - actual and forecast

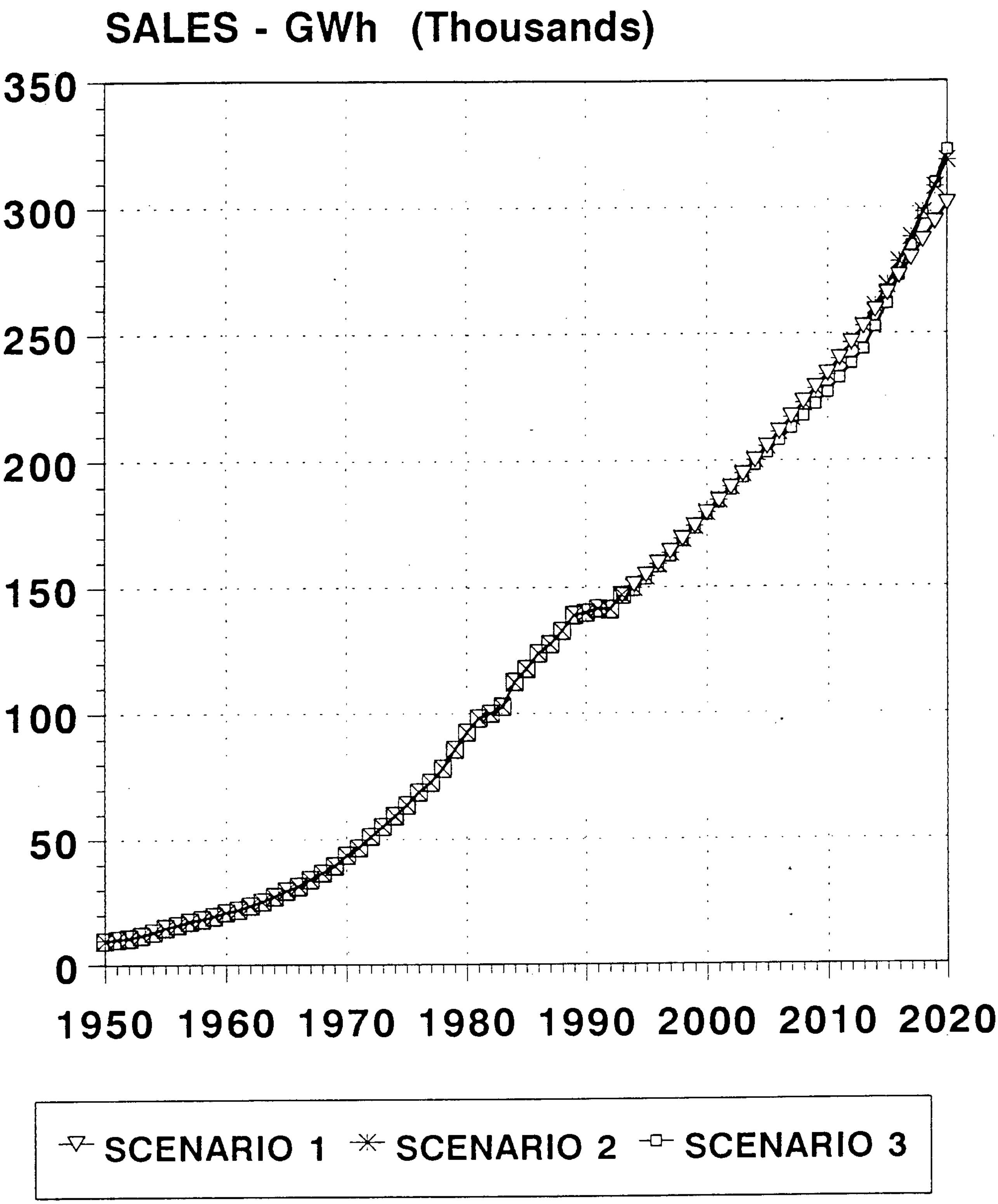



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Figure 4.9 Electricity generation - actual and forecast

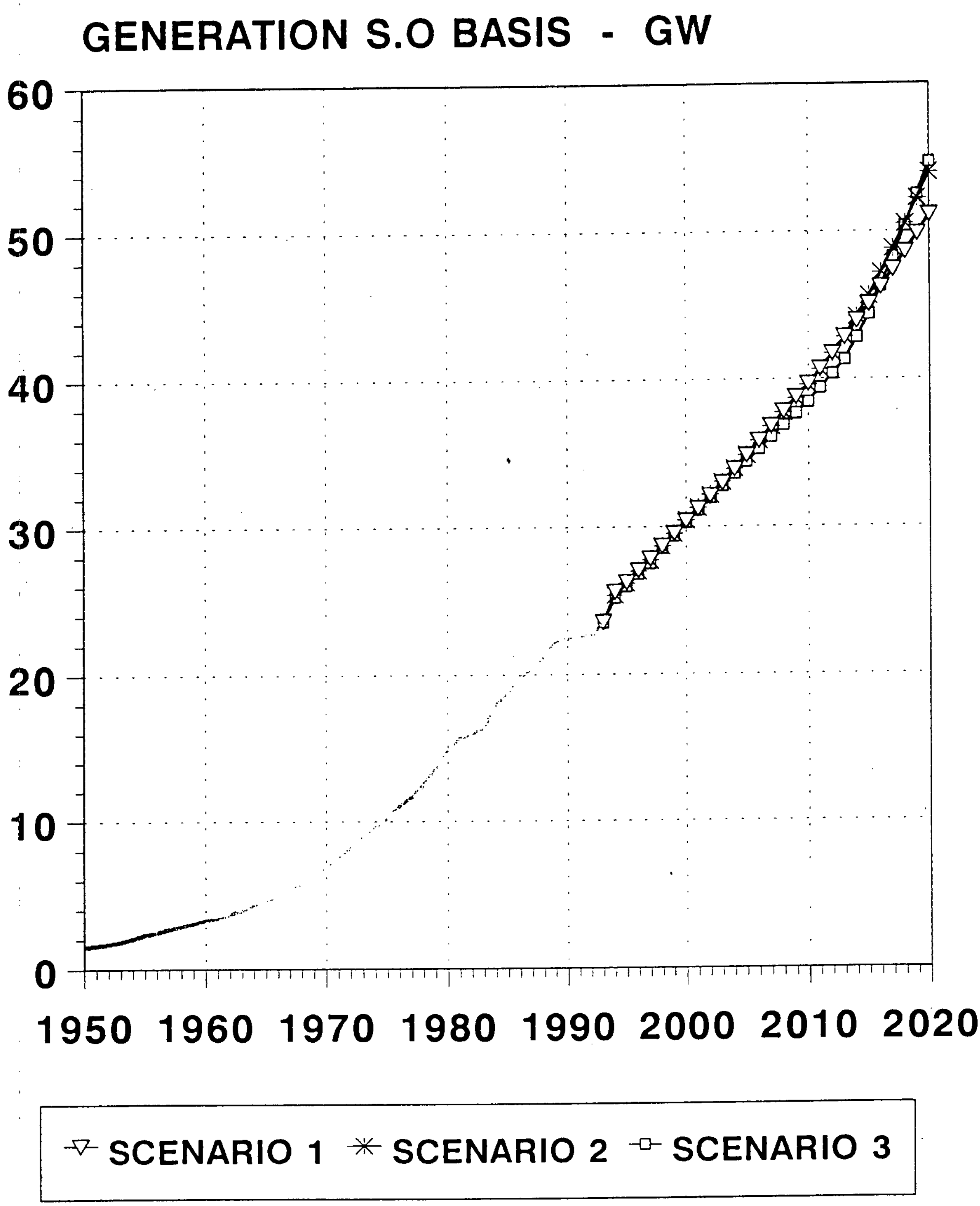


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Figure 4.10 South Africa's capacity installation programme and capacity requirements in the future

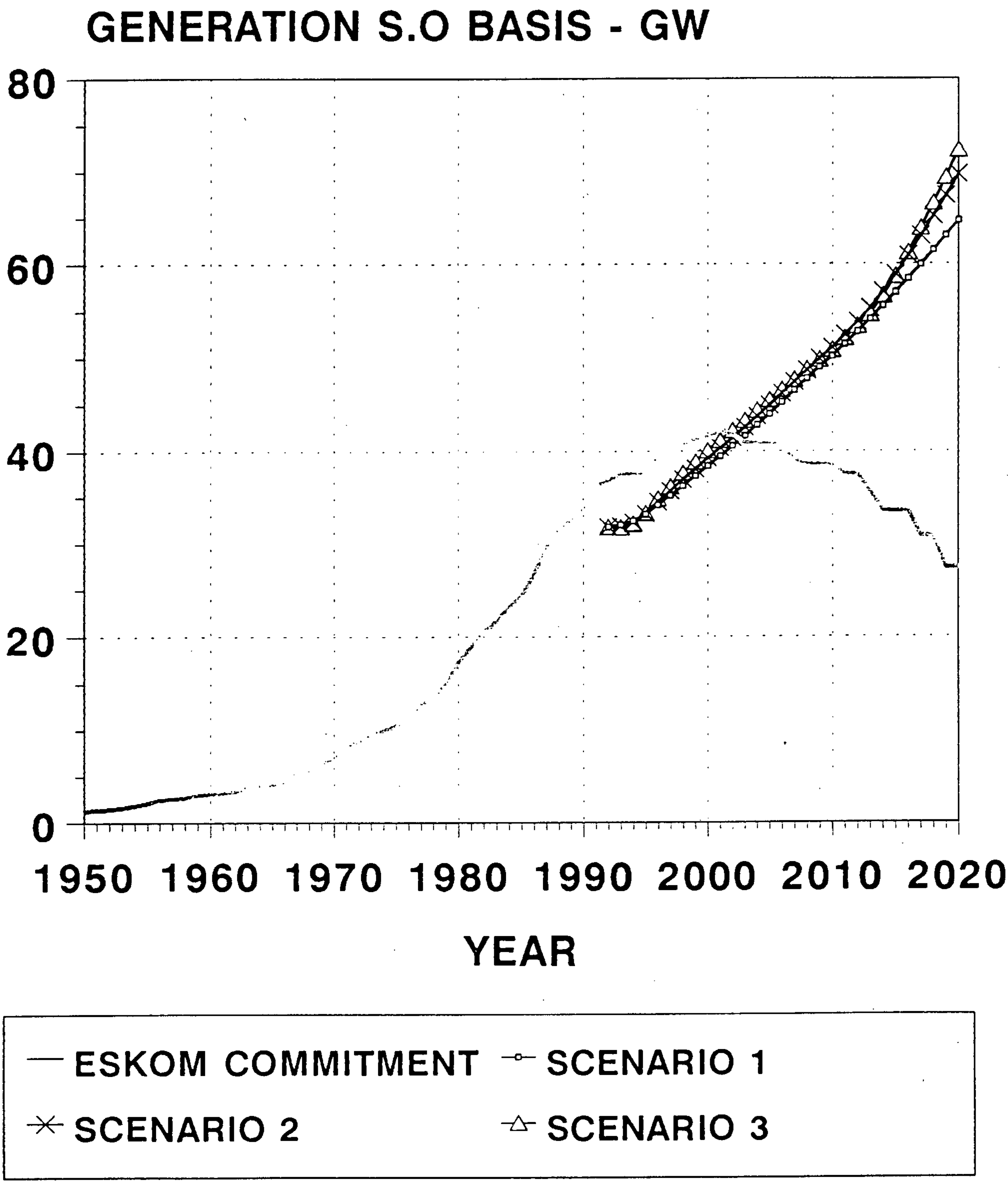


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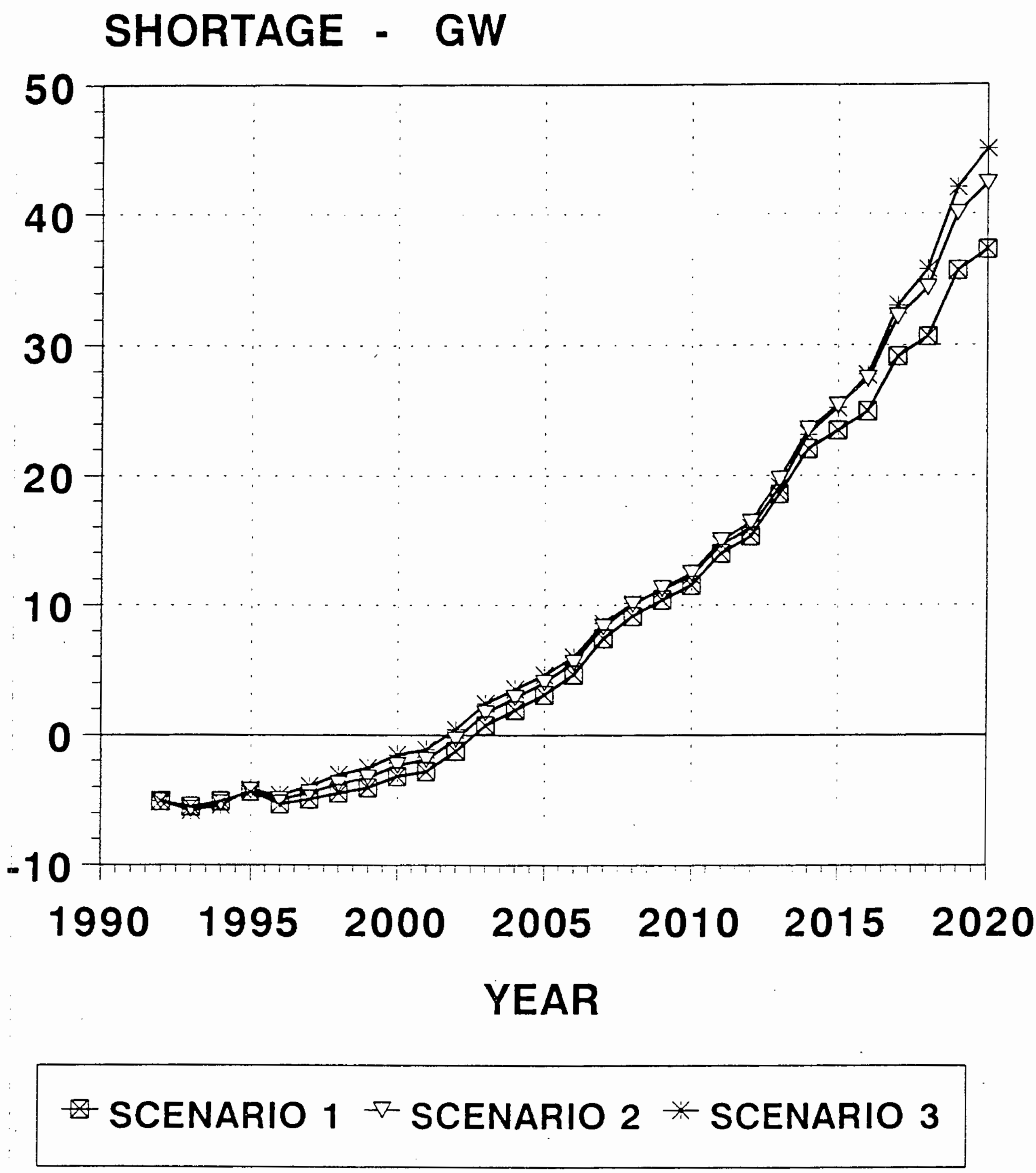
Figure 4.11 Capacity surplus and shortage on the ESKOM system




SA 4.11

Figure 4.12 Electricity import potential into the South African system

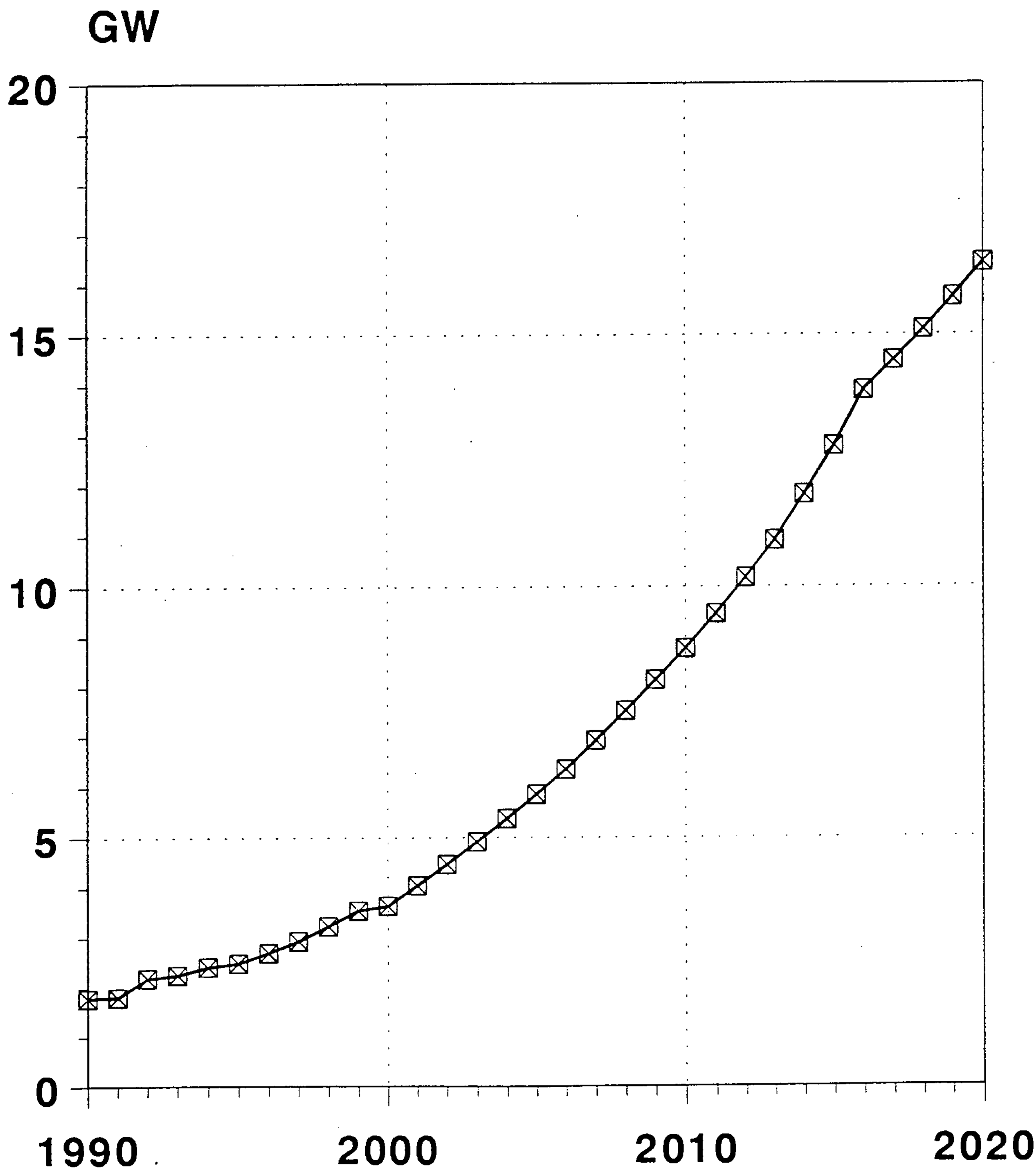



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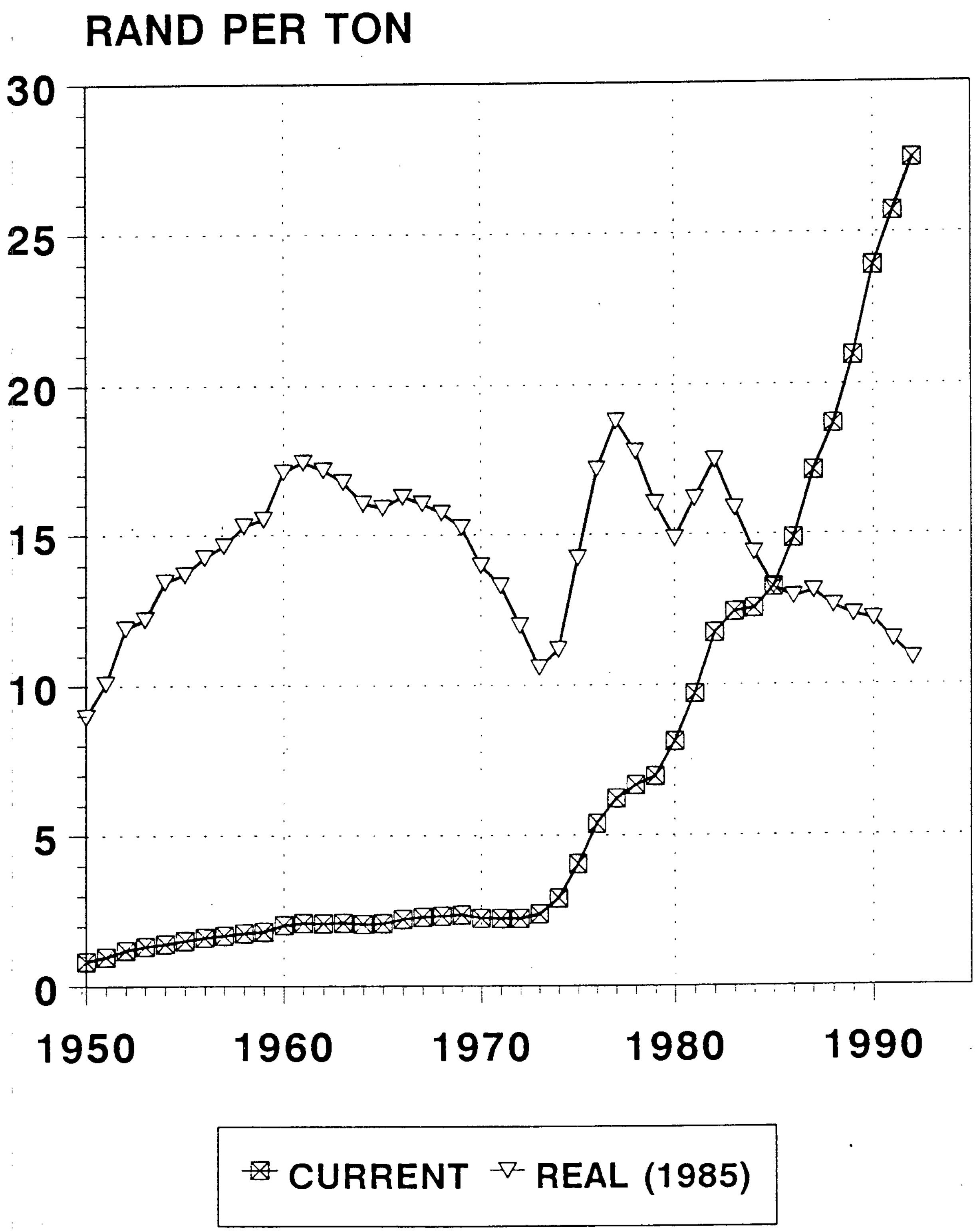
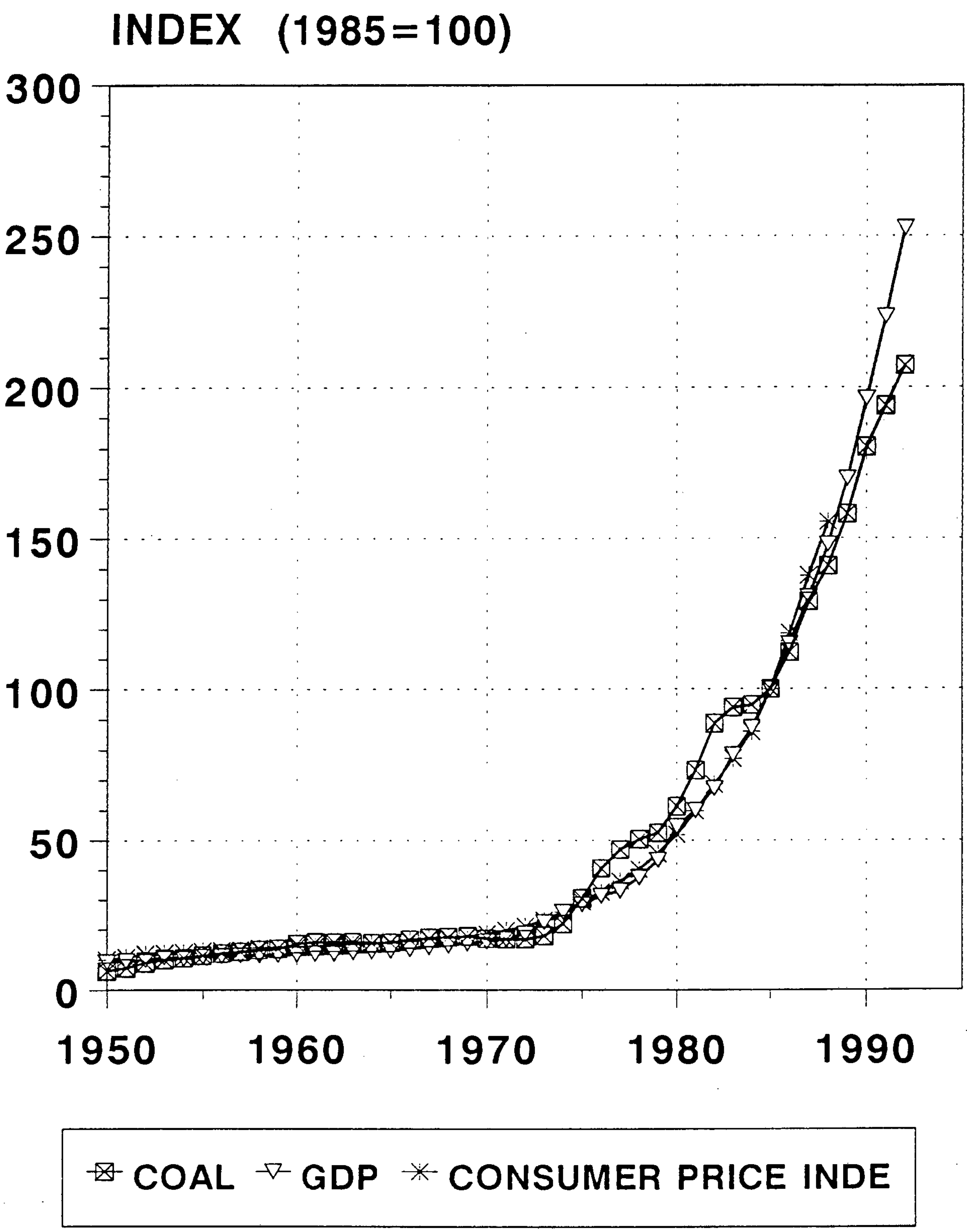
Figure 4.13 Coal cost to ESKOM - current and real (1985 Rand)



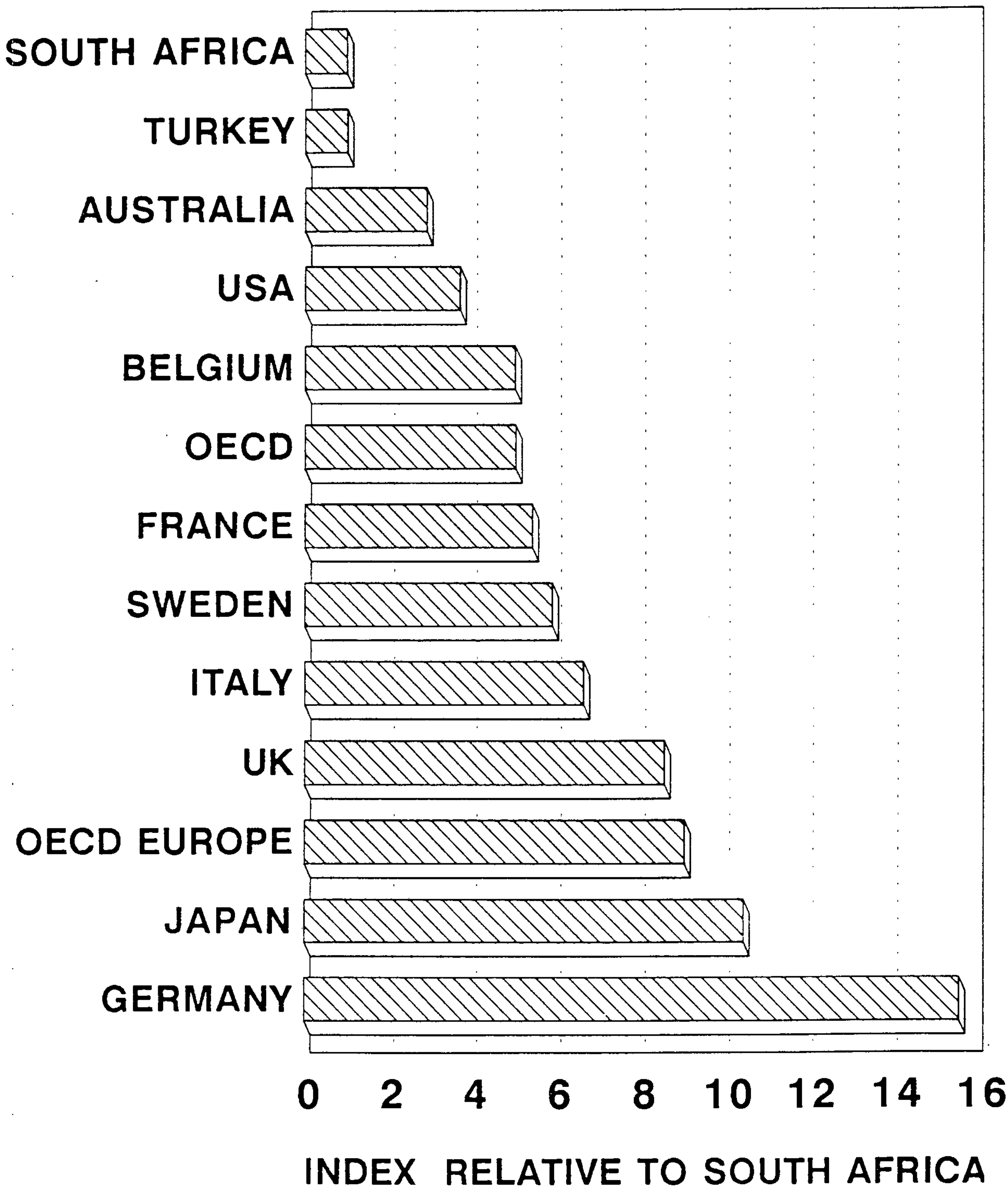

SA 4.13

Figure 4.14 GDP, ESKOM coal and consumer price indices relative to 1985



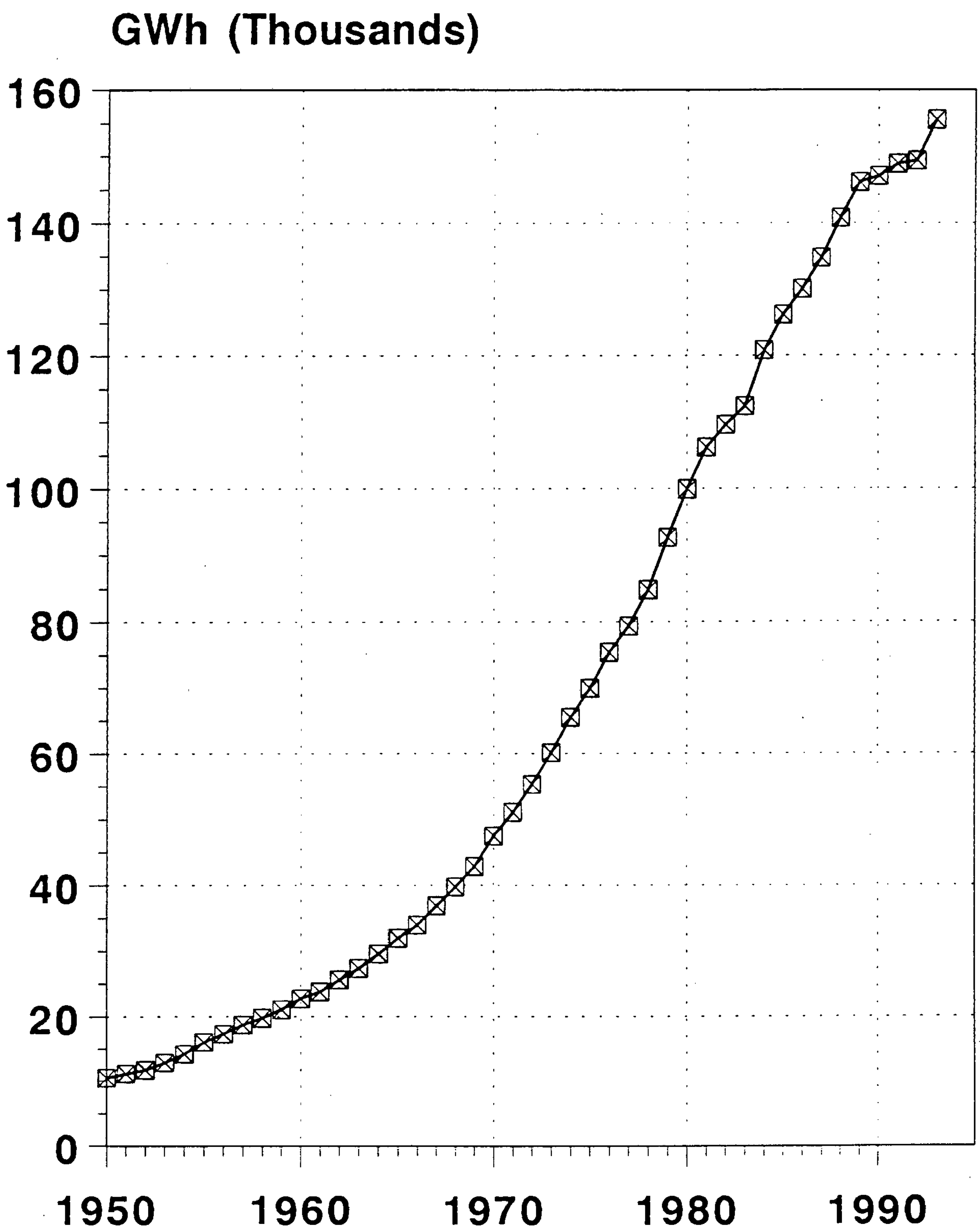

SA 4.14

Figure 4.15 International coal prices for electricity generation - 1990



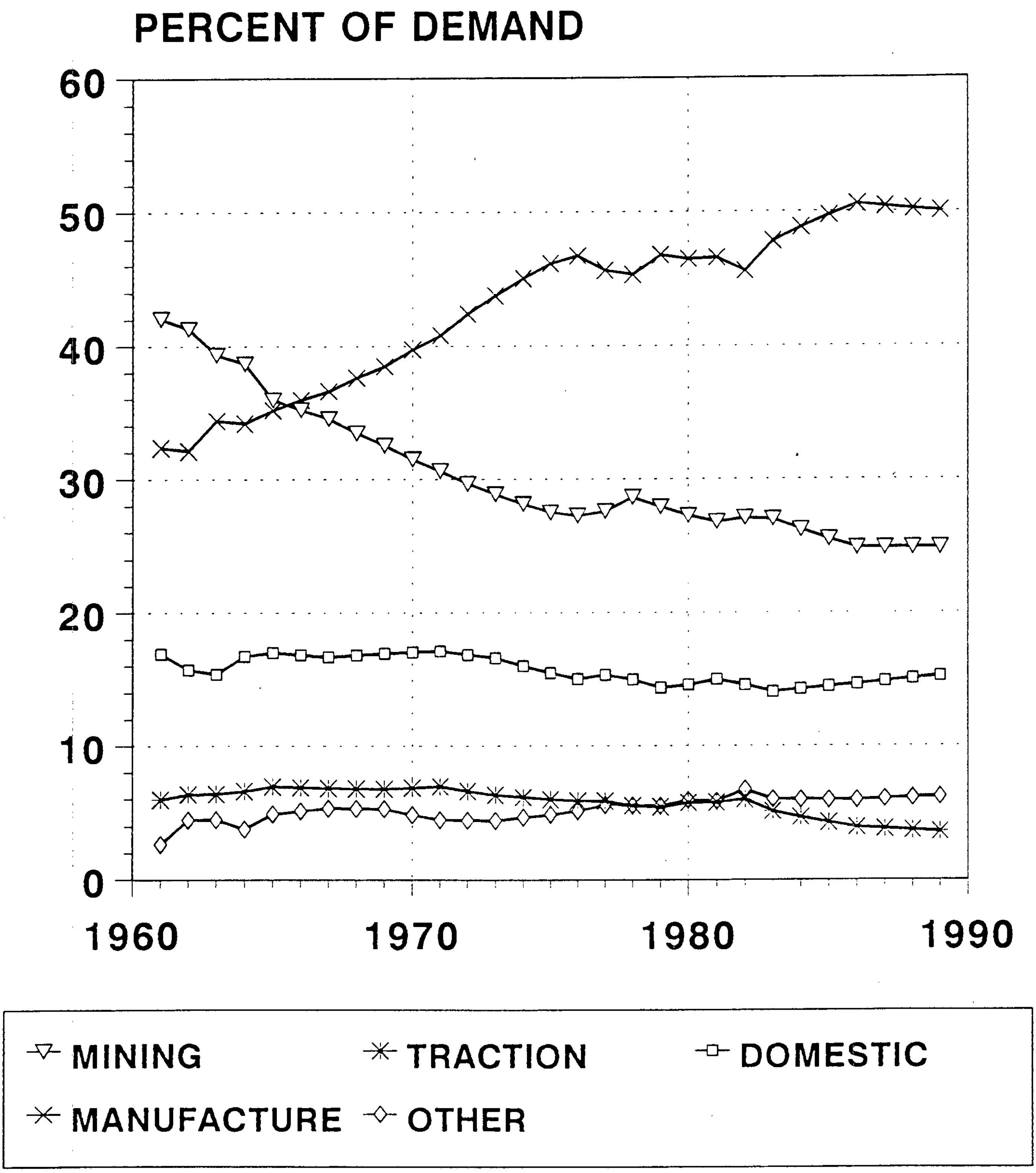

SA 4.15

**Figure 4.16 Electricity sales (SA total)**




SA 4.16

Figure 4.17 South Africa electricity usage percent of market




SA 4.17

Figure 4.18 South Africa electricity usage sales by sector

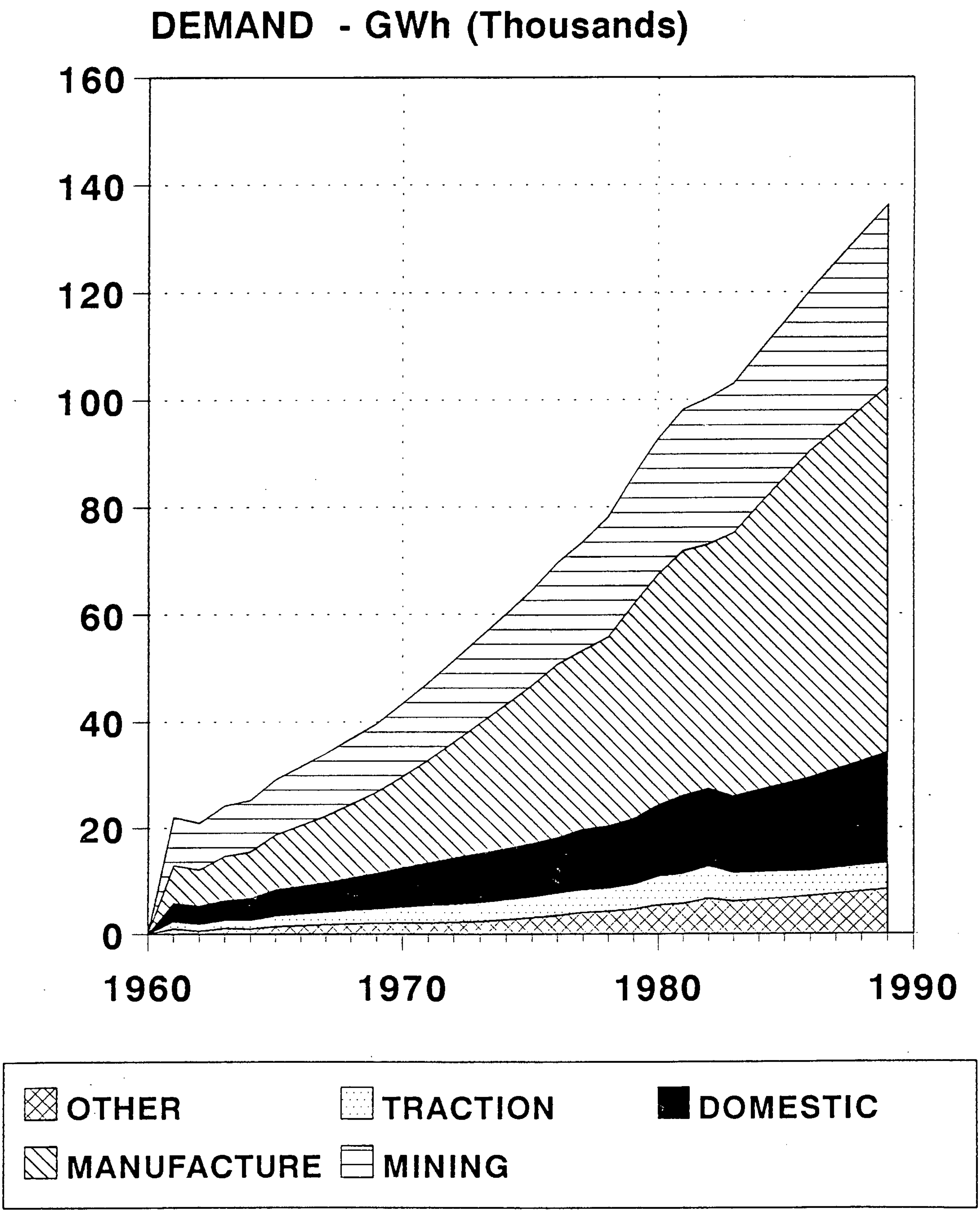



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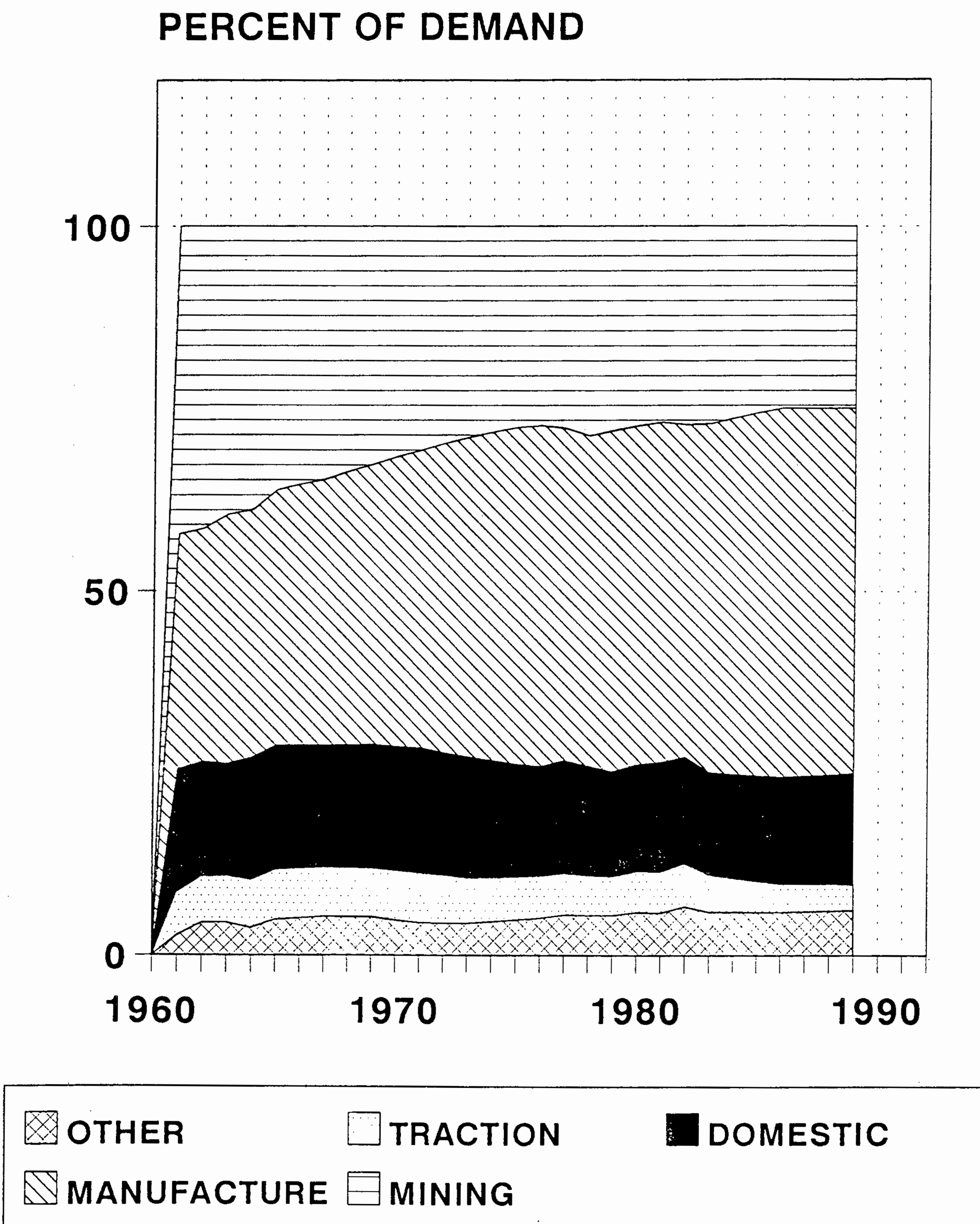
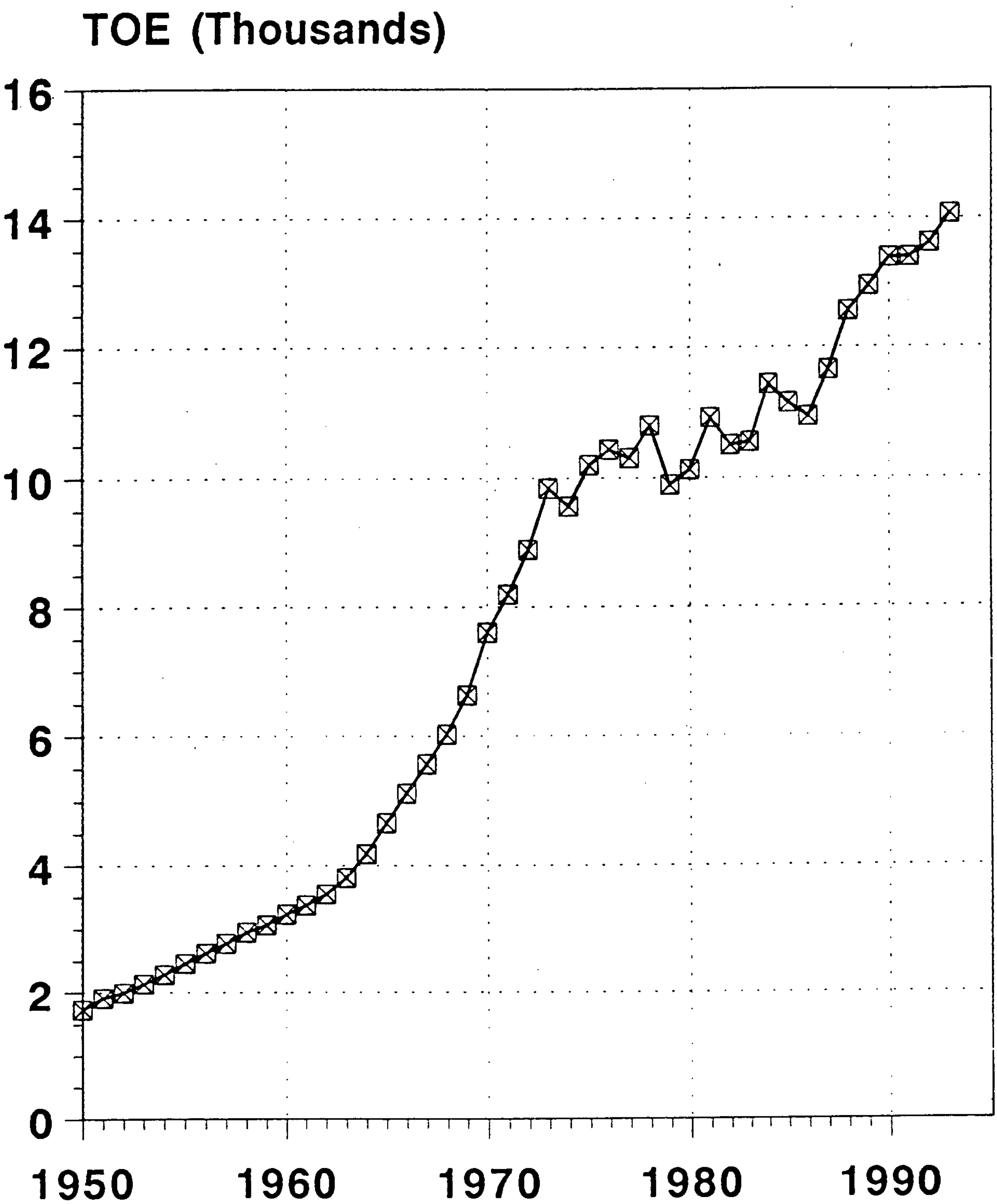
Figure 4.19 South Africa electricity usage percent of market



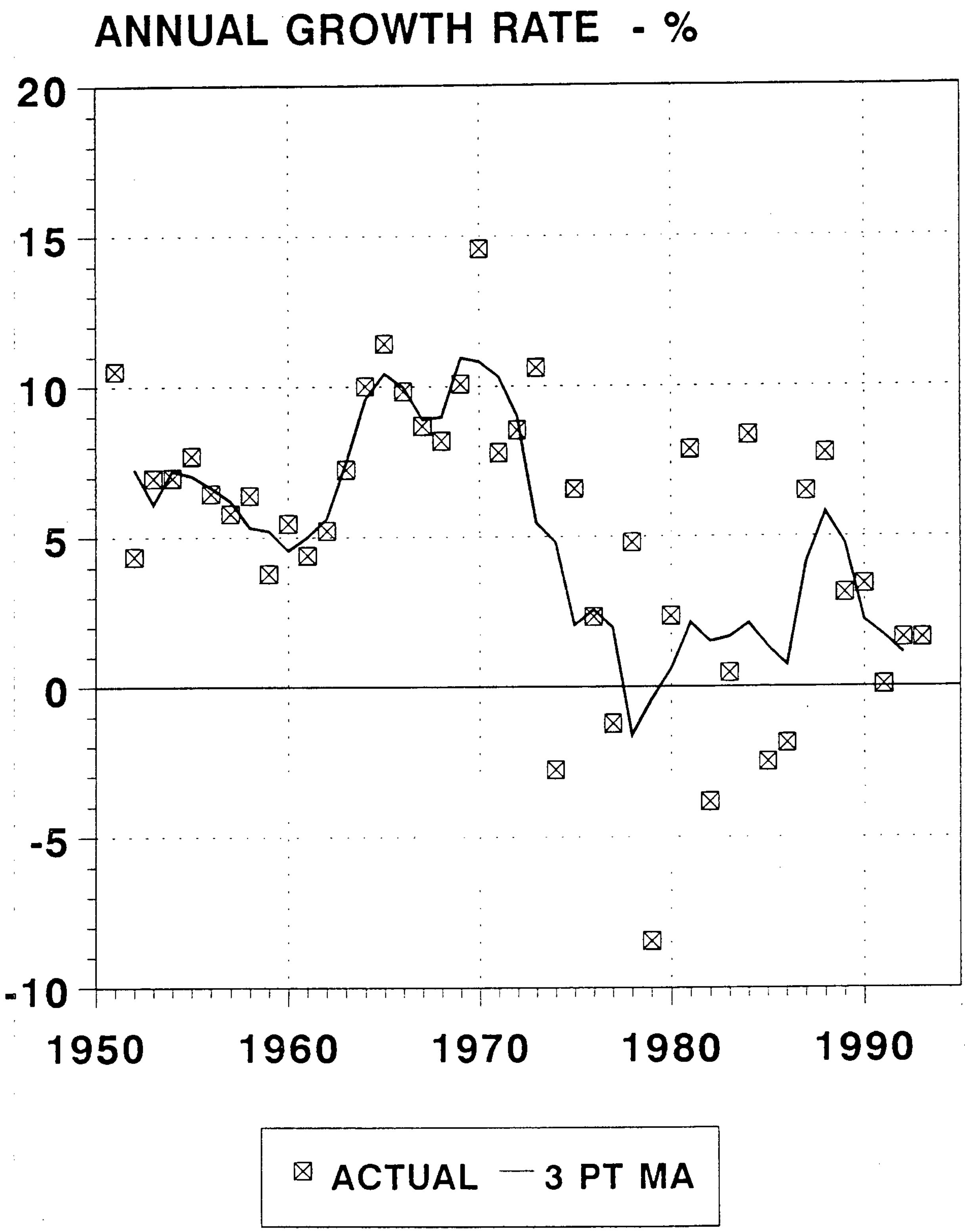

SA 4.19

Figure 5.1 Liquid fuel consumption in the final sector (tons Oil Equivalent)



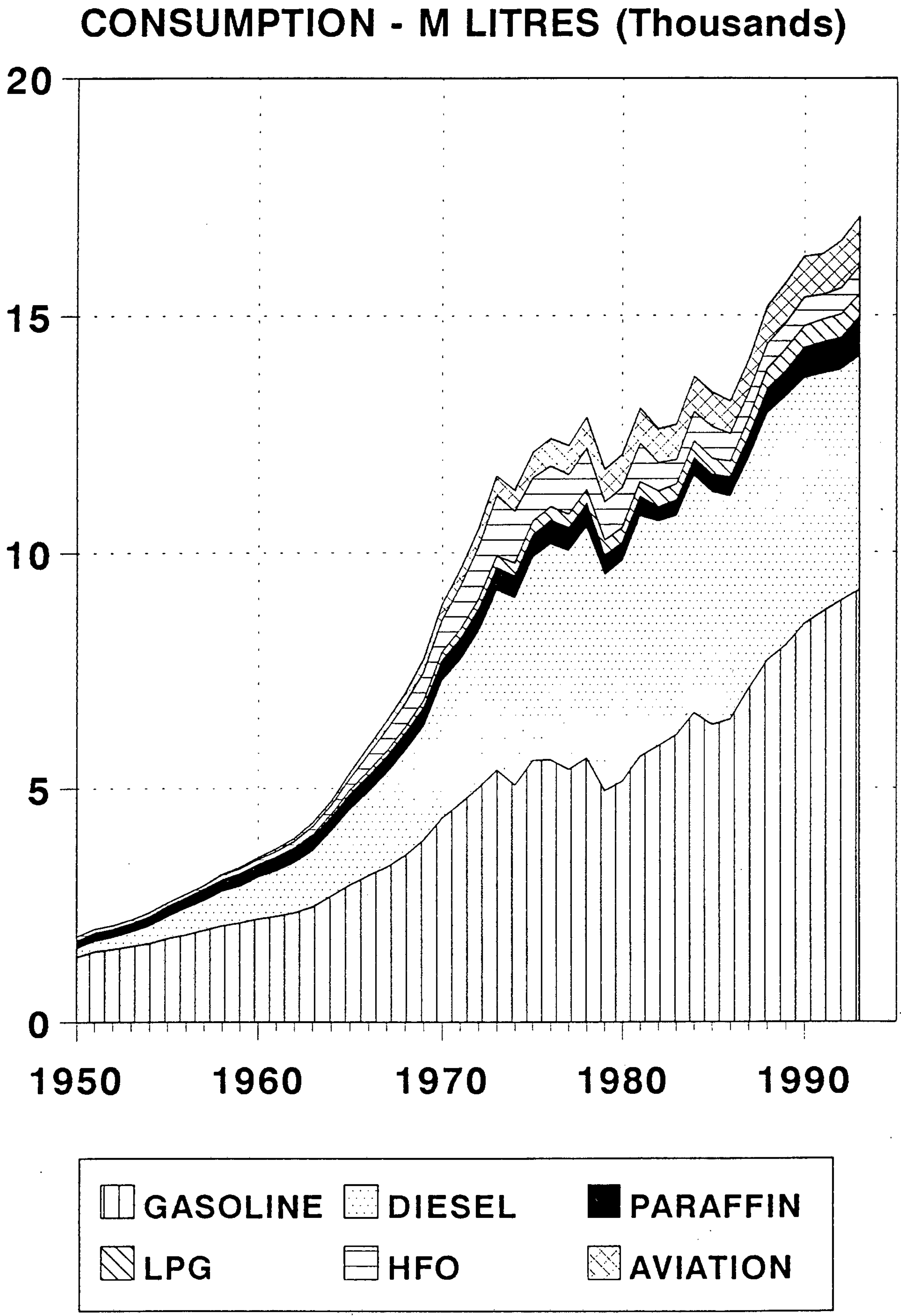

SA 5.1

Figure 5.2 Annual growth rate in liquid fuel consumption



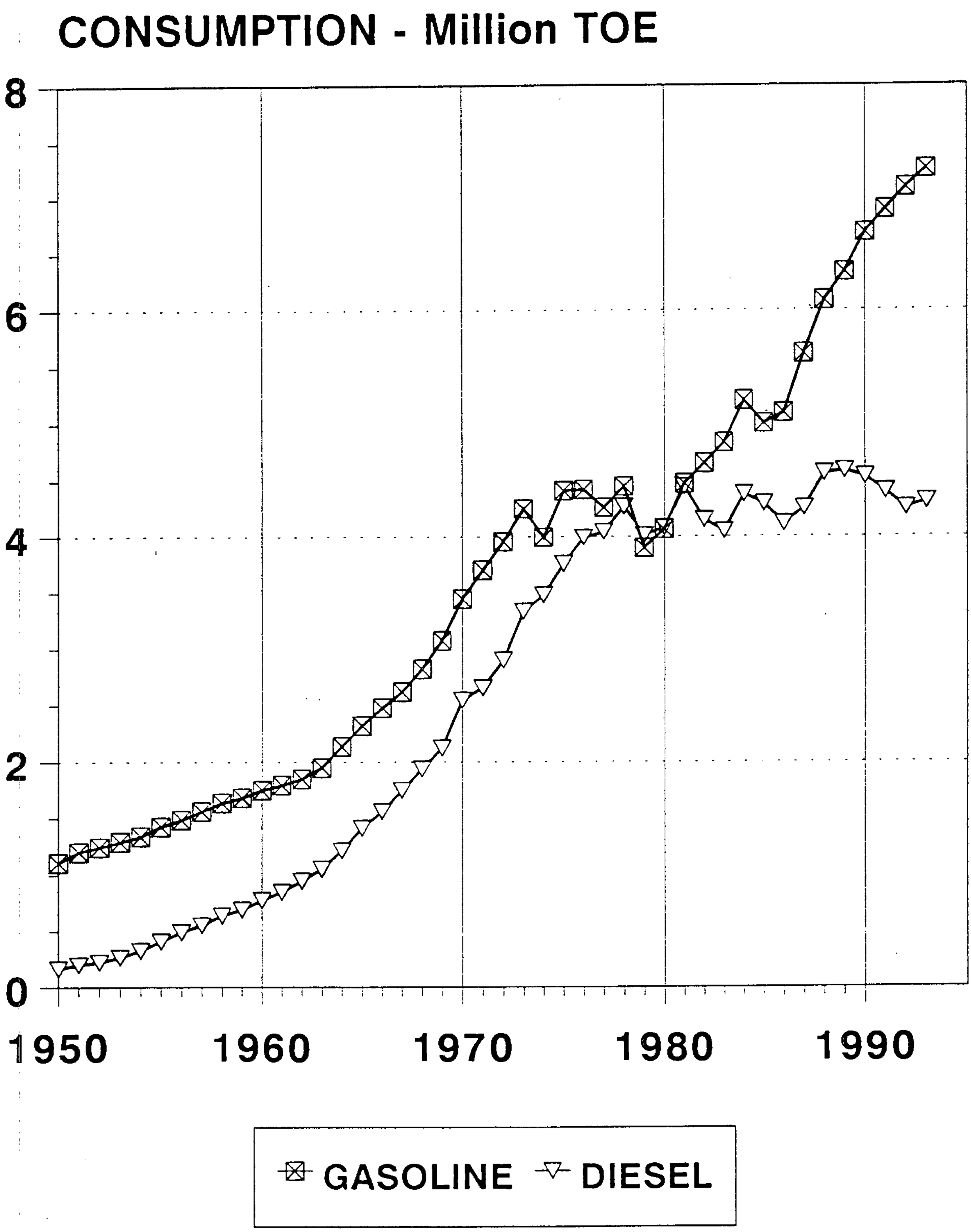

SA 5.2

Figure 5.3 Liquid fuel product consumption by type



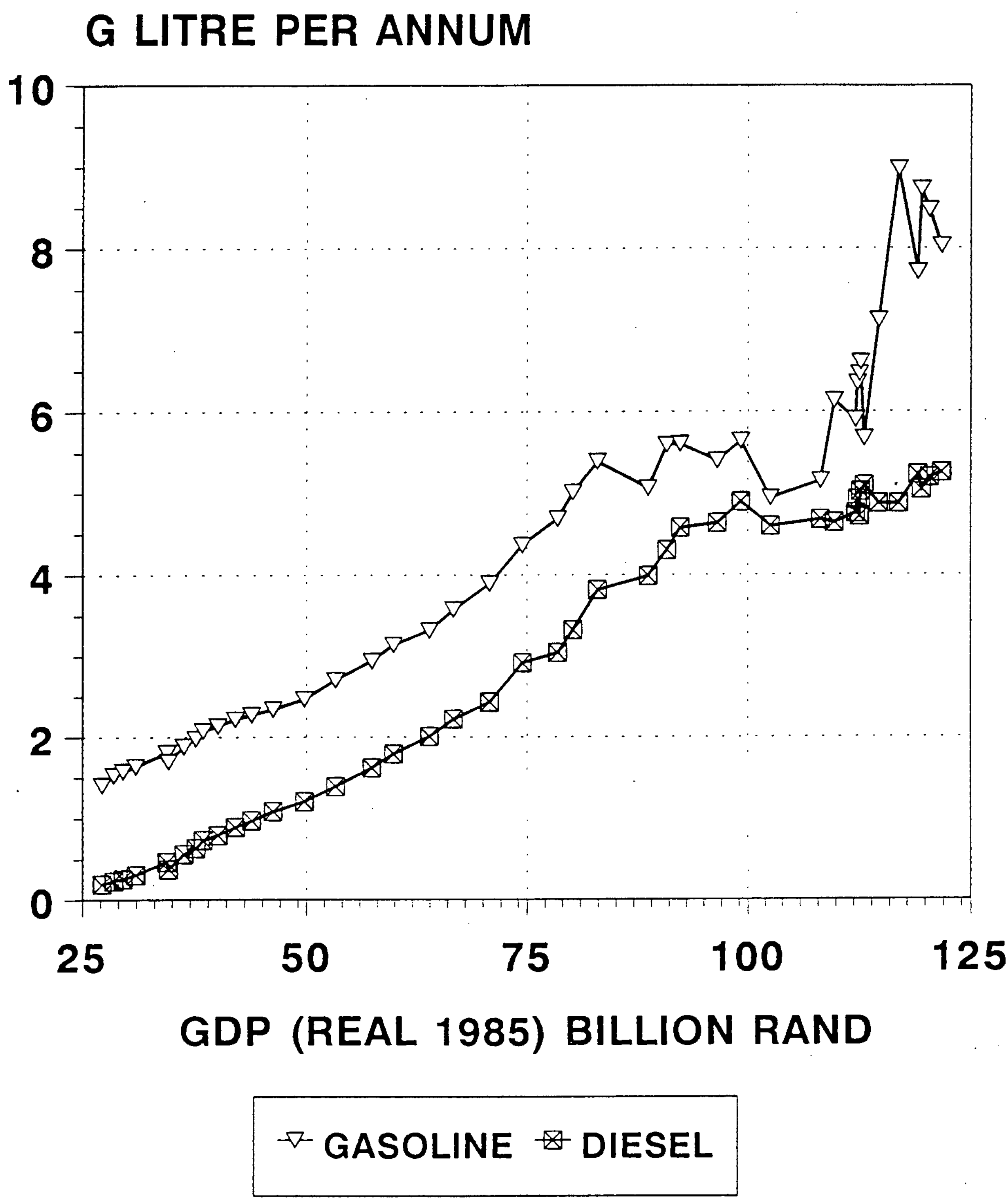

SA 5.3

Figure 5.4 Gasoline and diesel consumption (Tons Oil Equivalent)



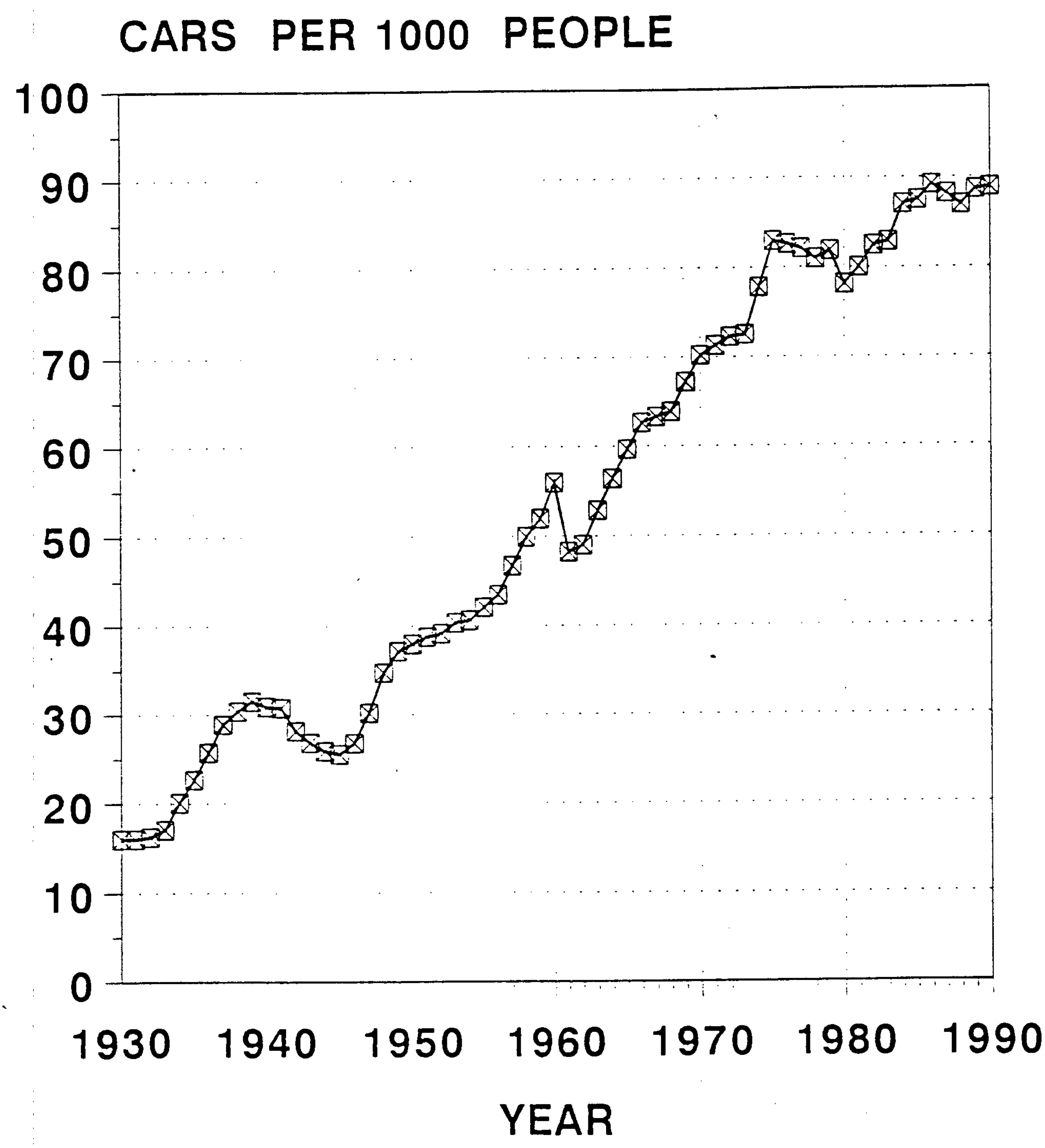

SA 5.4

Figure 5.5 Fuel consumption vs GDP




SA 5.5

Figure 5.6 Passenger vehicles per 1000 of population




SA 5.6

Figure 5.7 New vehicle sales

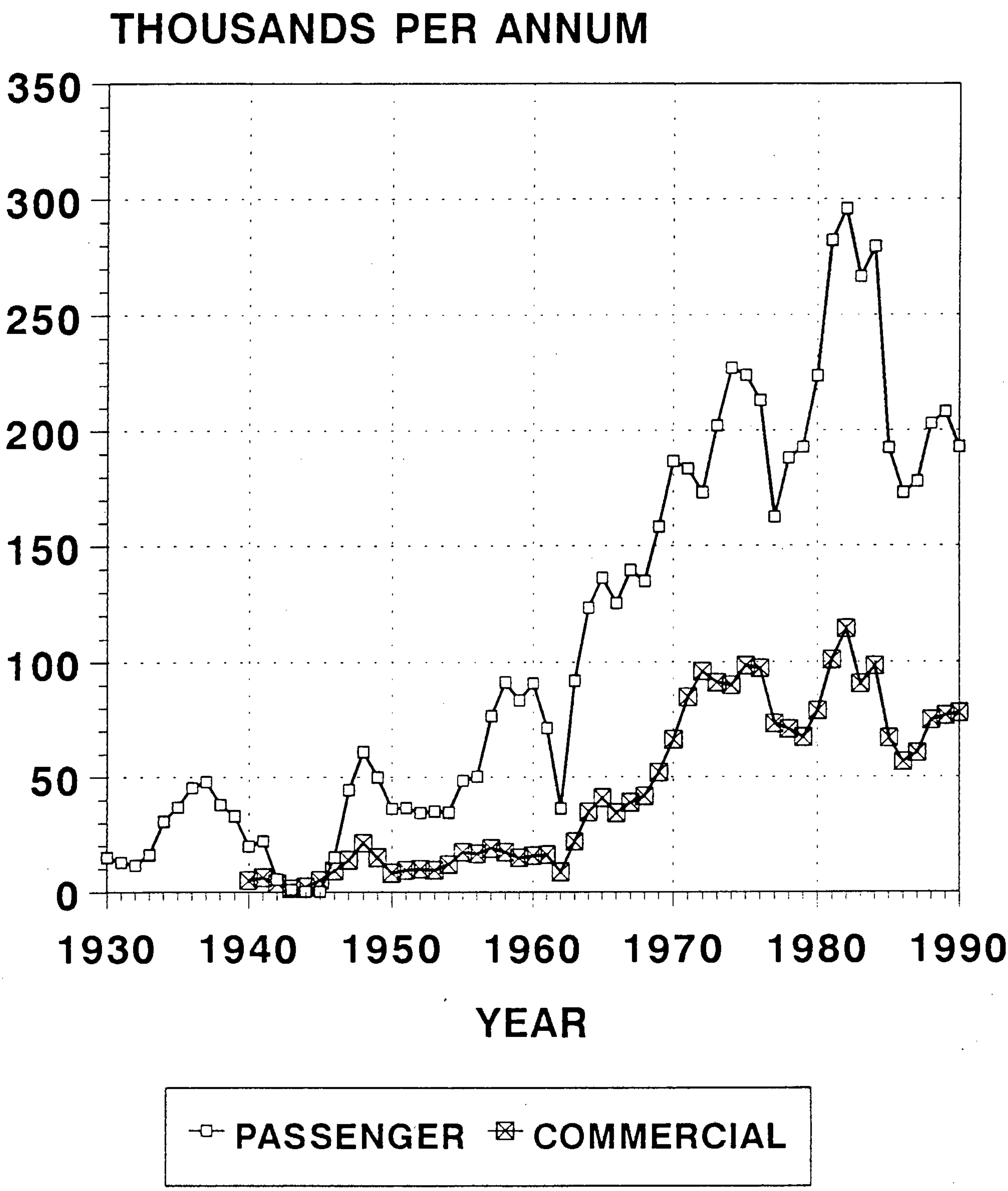



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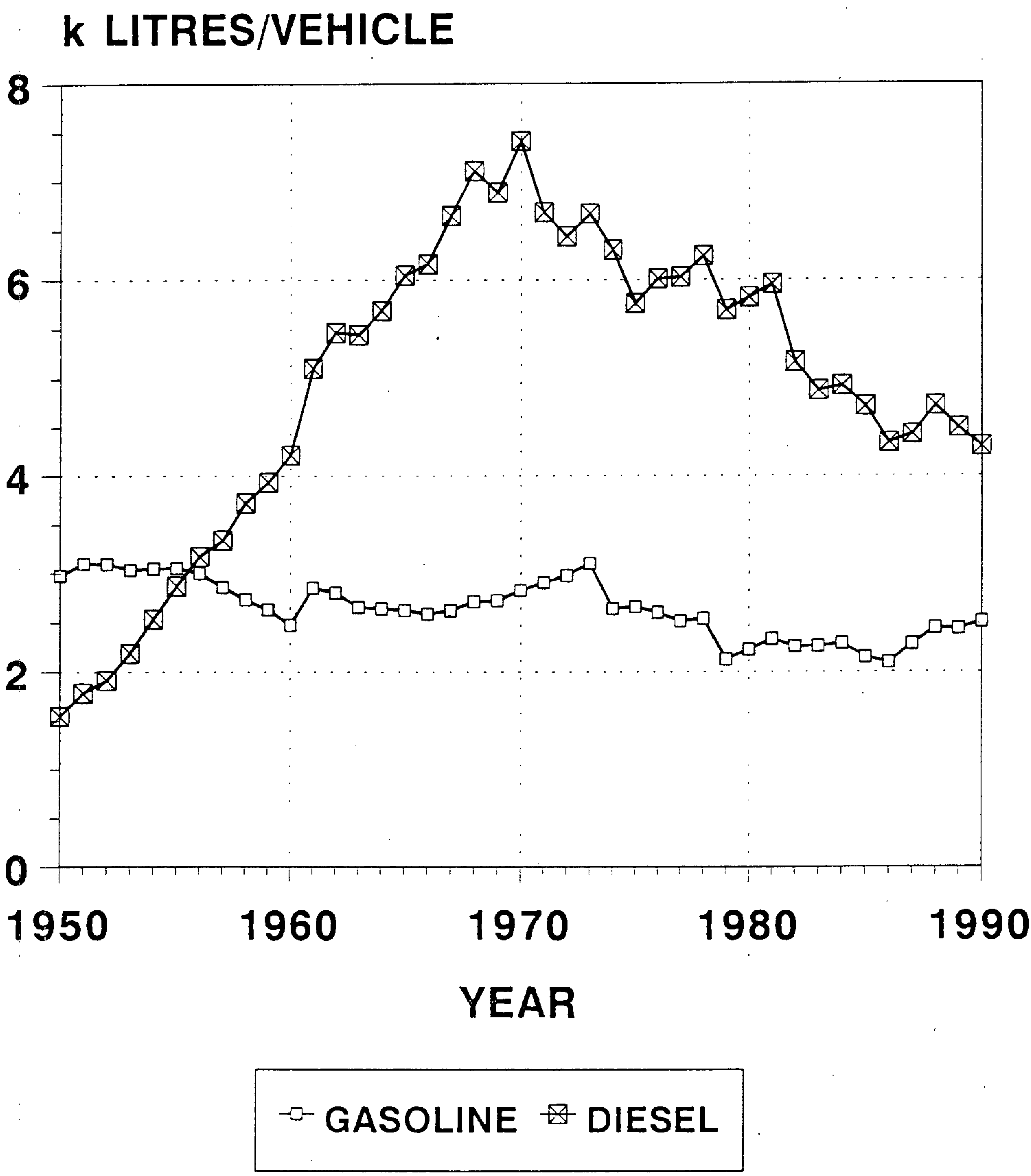
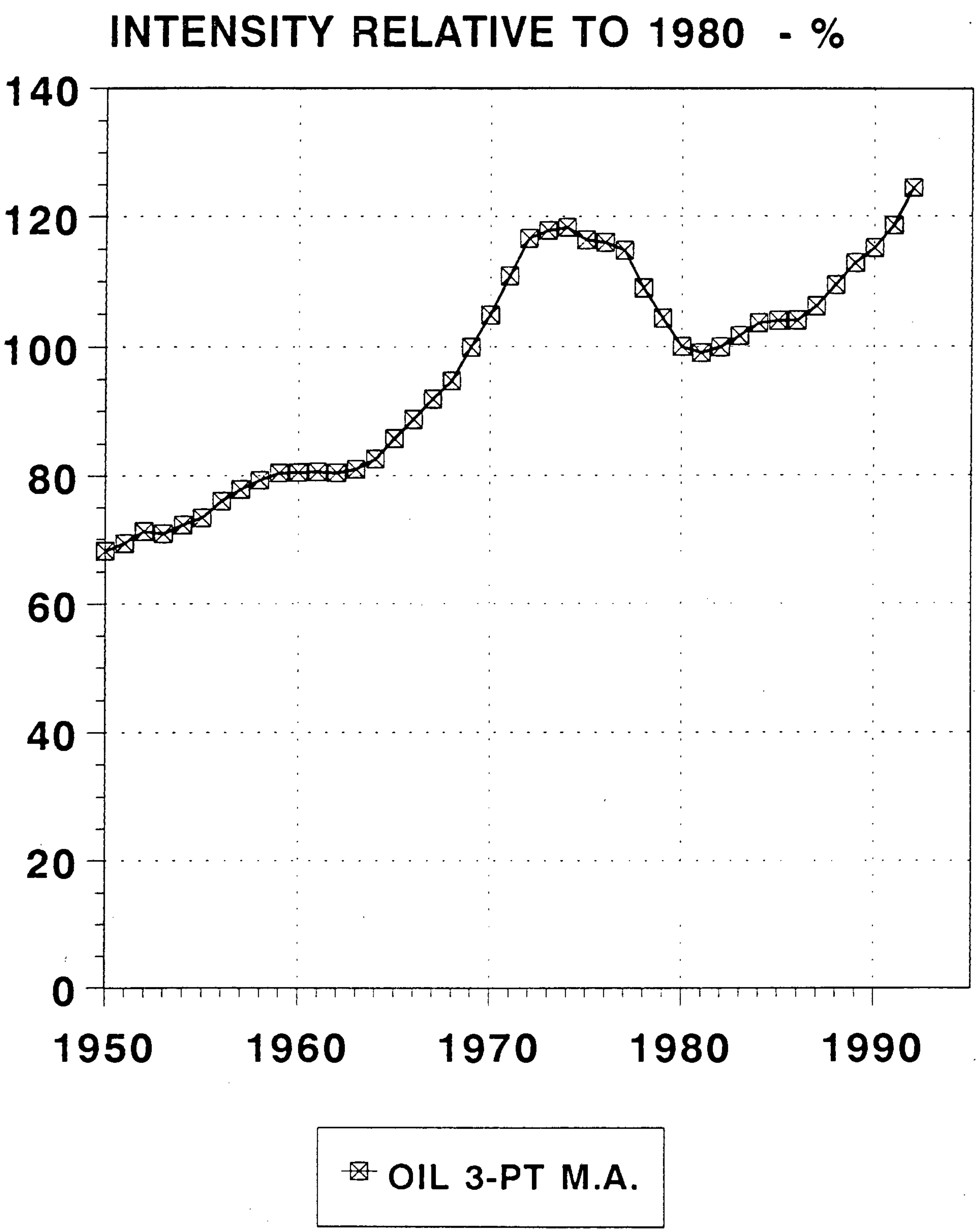
Figure 5.8 Fuel usage per vehicle




SA 5.8

Figure 5.9 Oil relative energy intensity




SA 5.9

Figure 5.10 Final oil consumption forecast

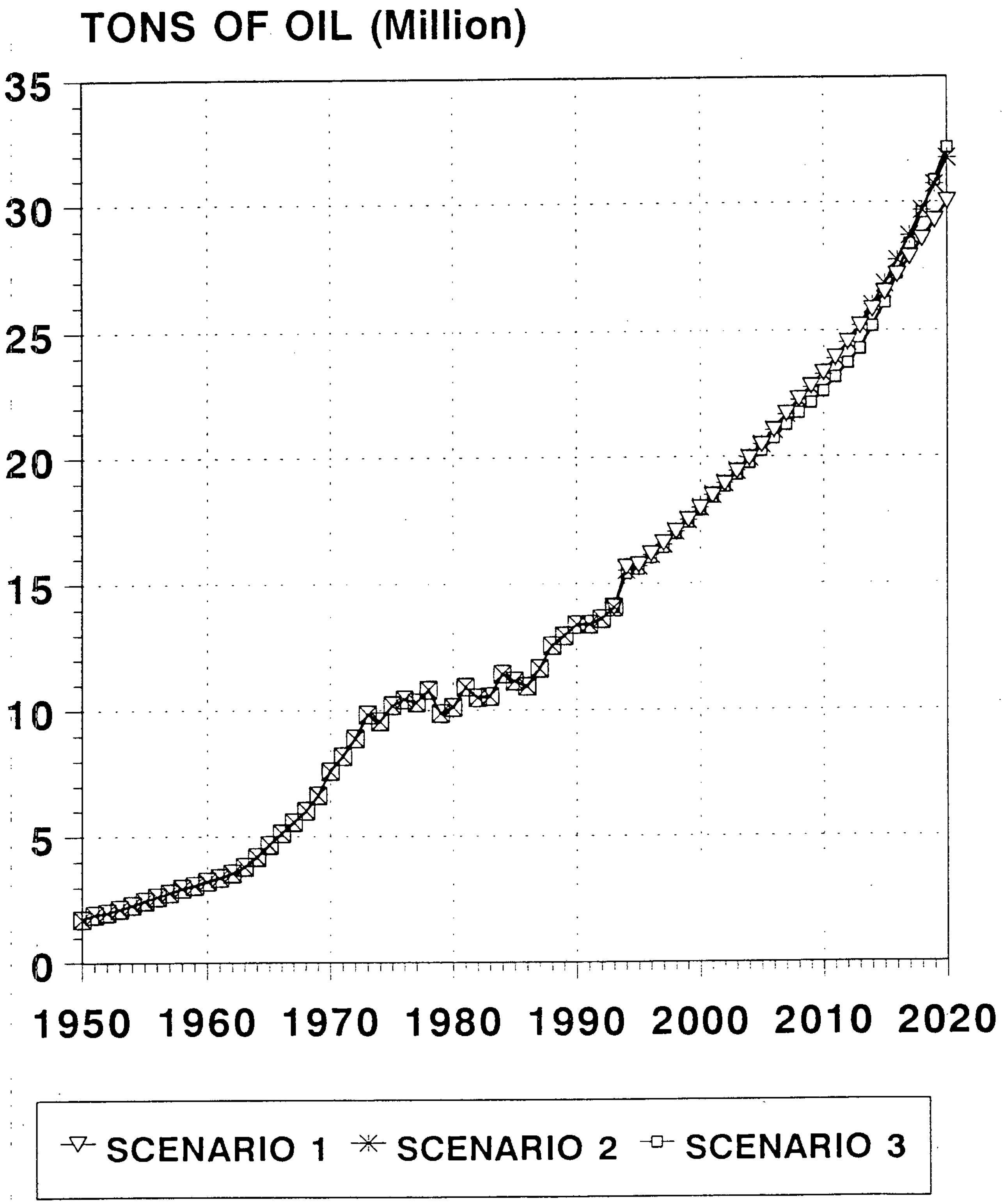



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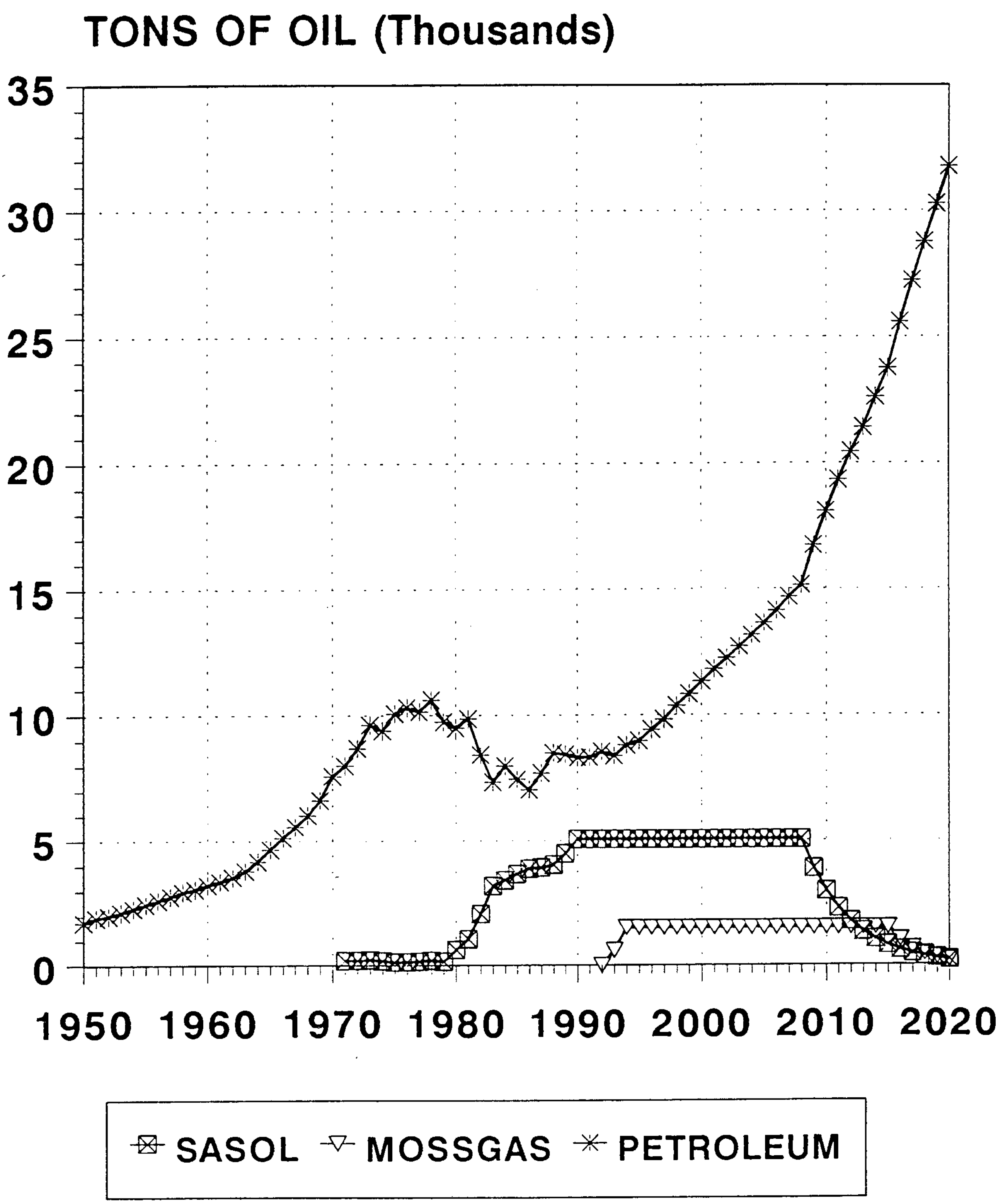
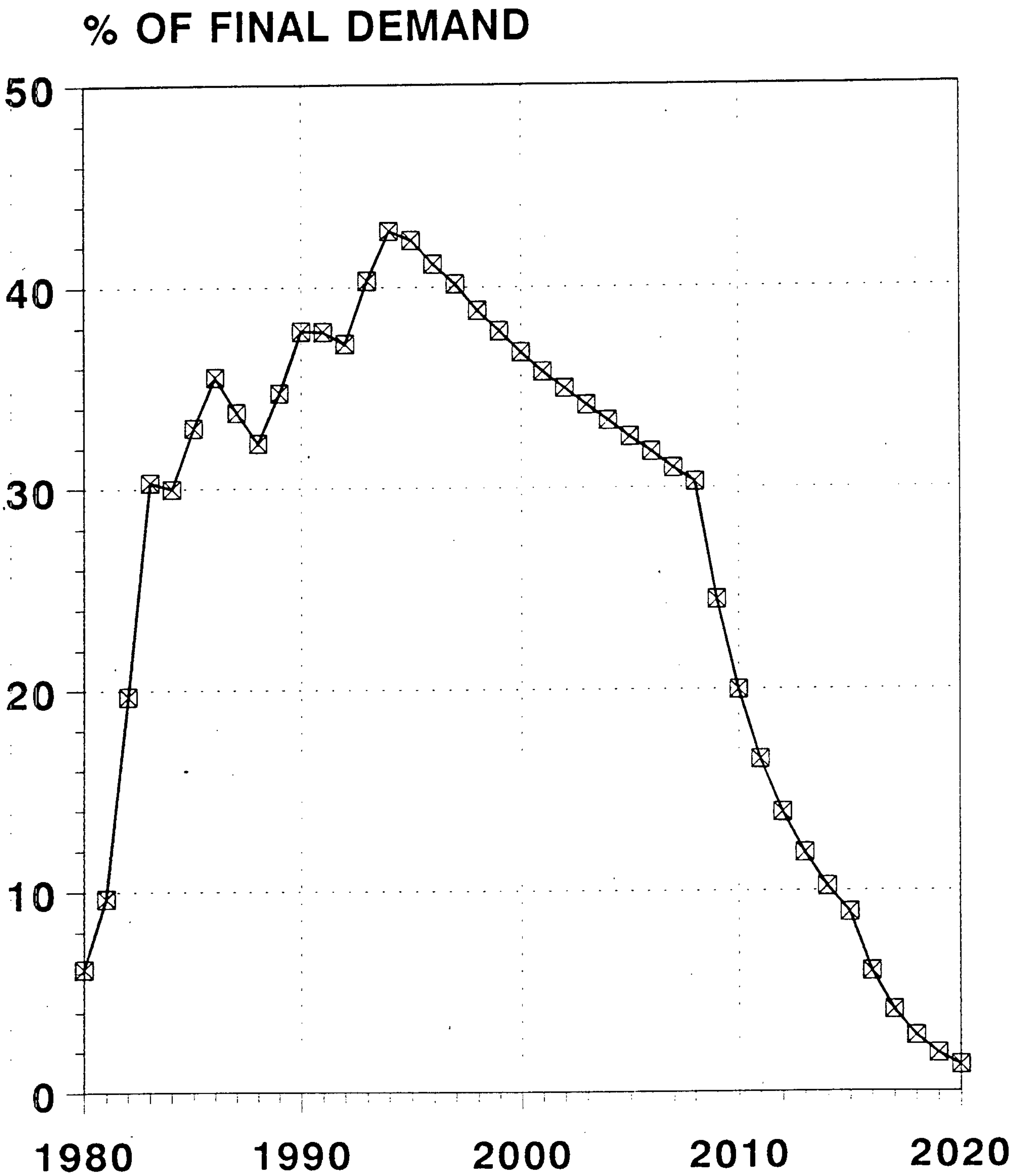
Figure 5.11 Oil production



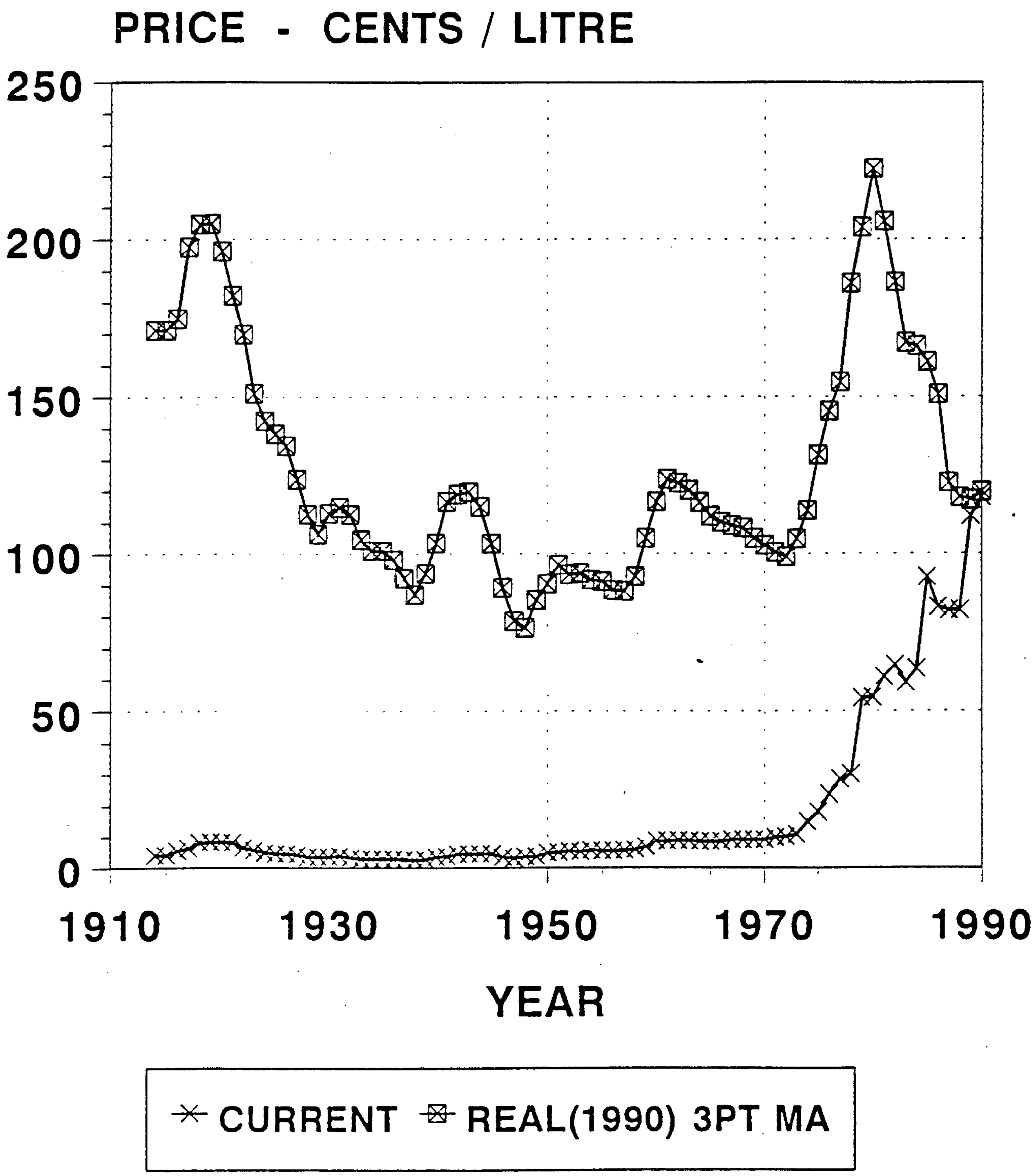

SA 5.11

Figure 5.12 Synthetic oil contribution to consumption



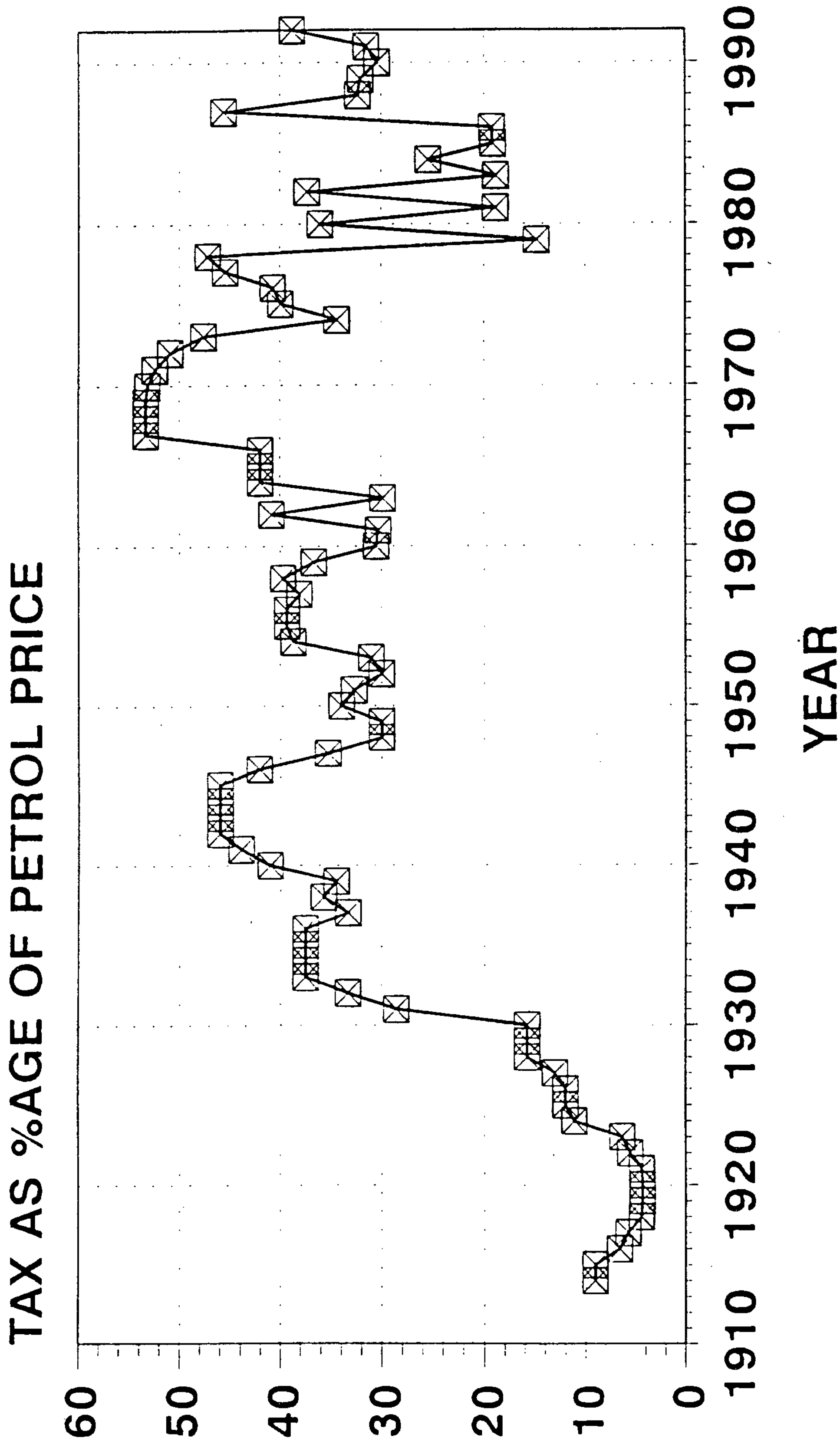

SA 5.12

Figure 5.13 Gasoline price - current and real



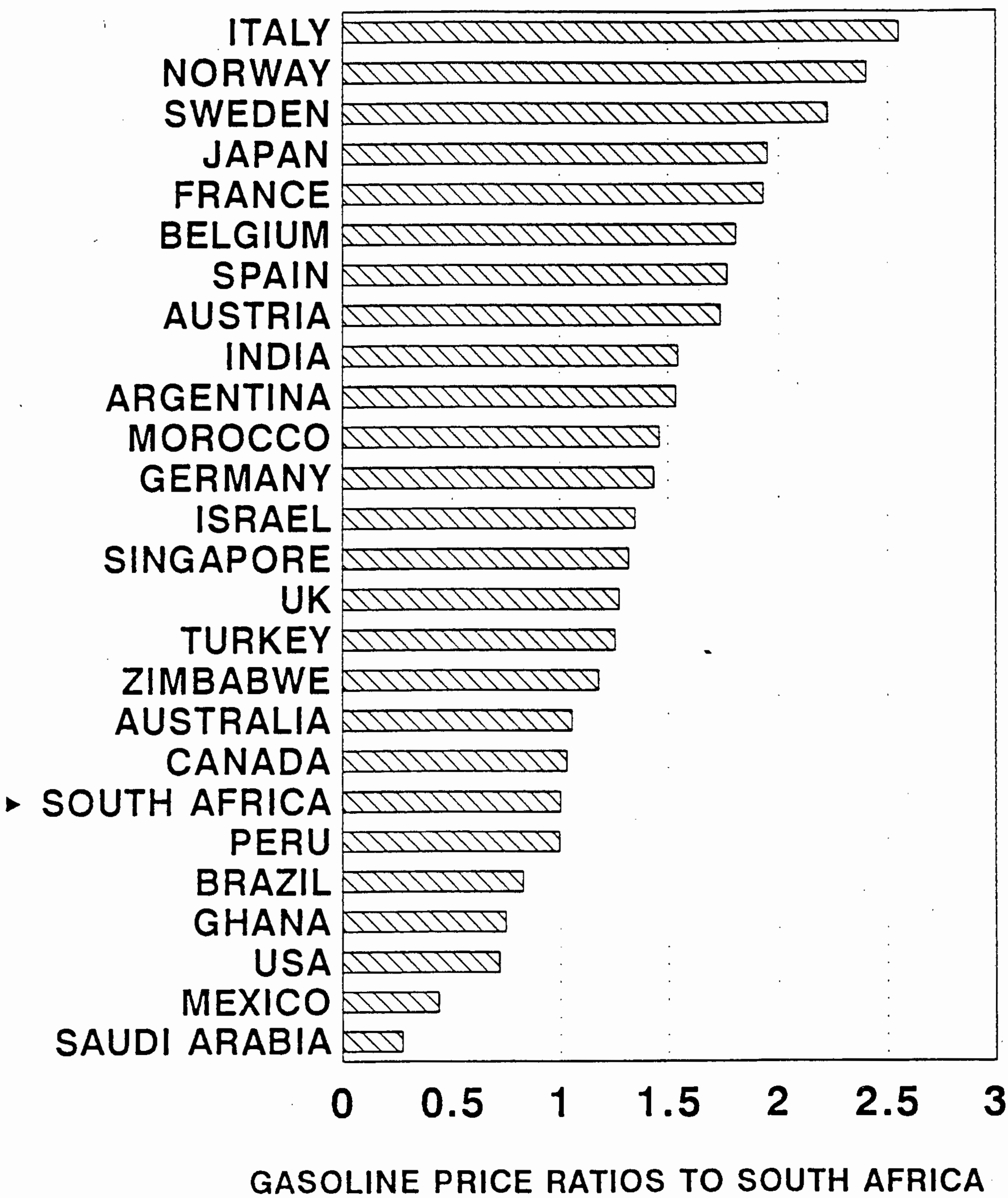

A 5.13

**Figure 5.14** Tax on gasoline - percent of total price



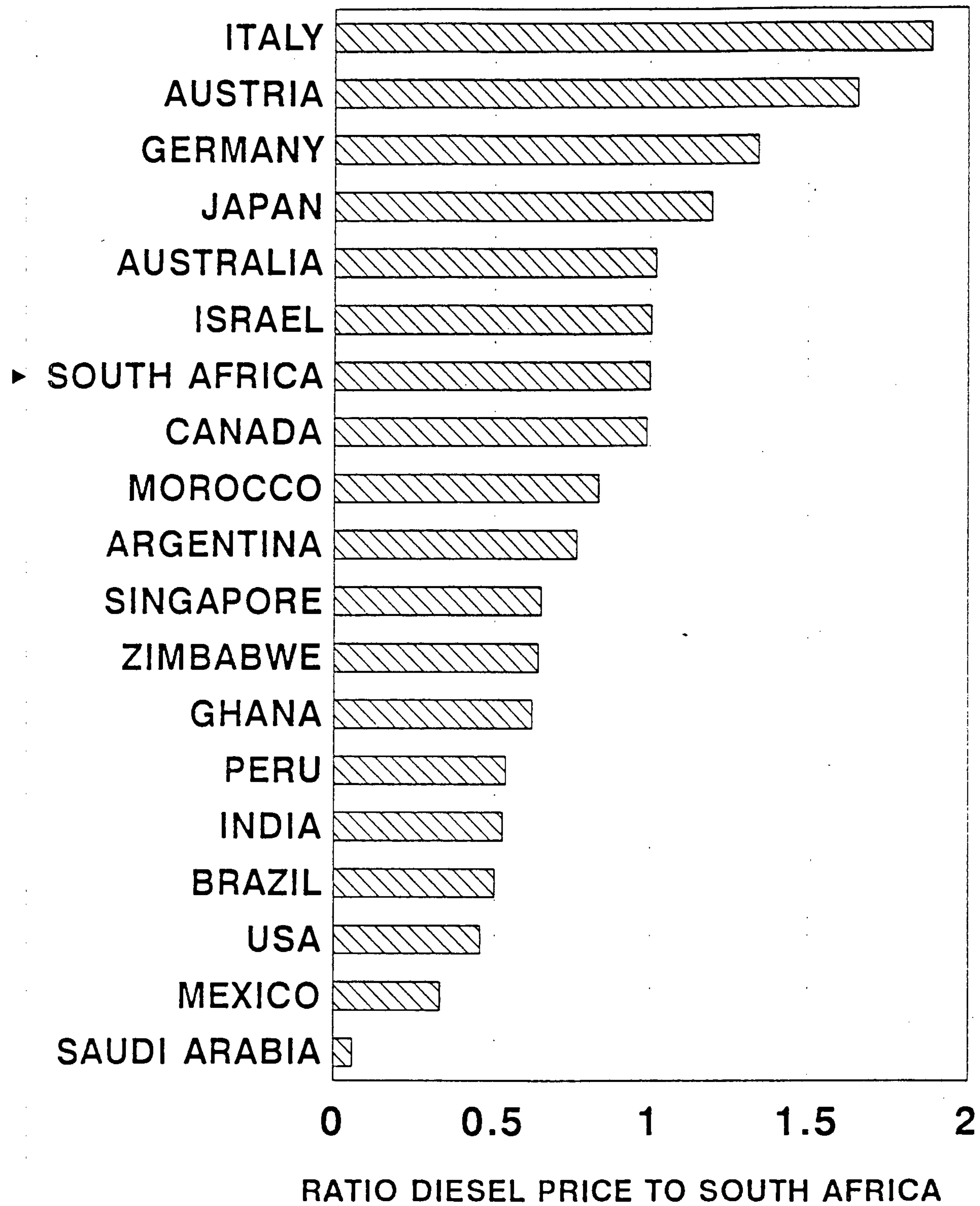

SA 5.14

Figure 5.15 International gasoline prices relative to South Africa (1990)



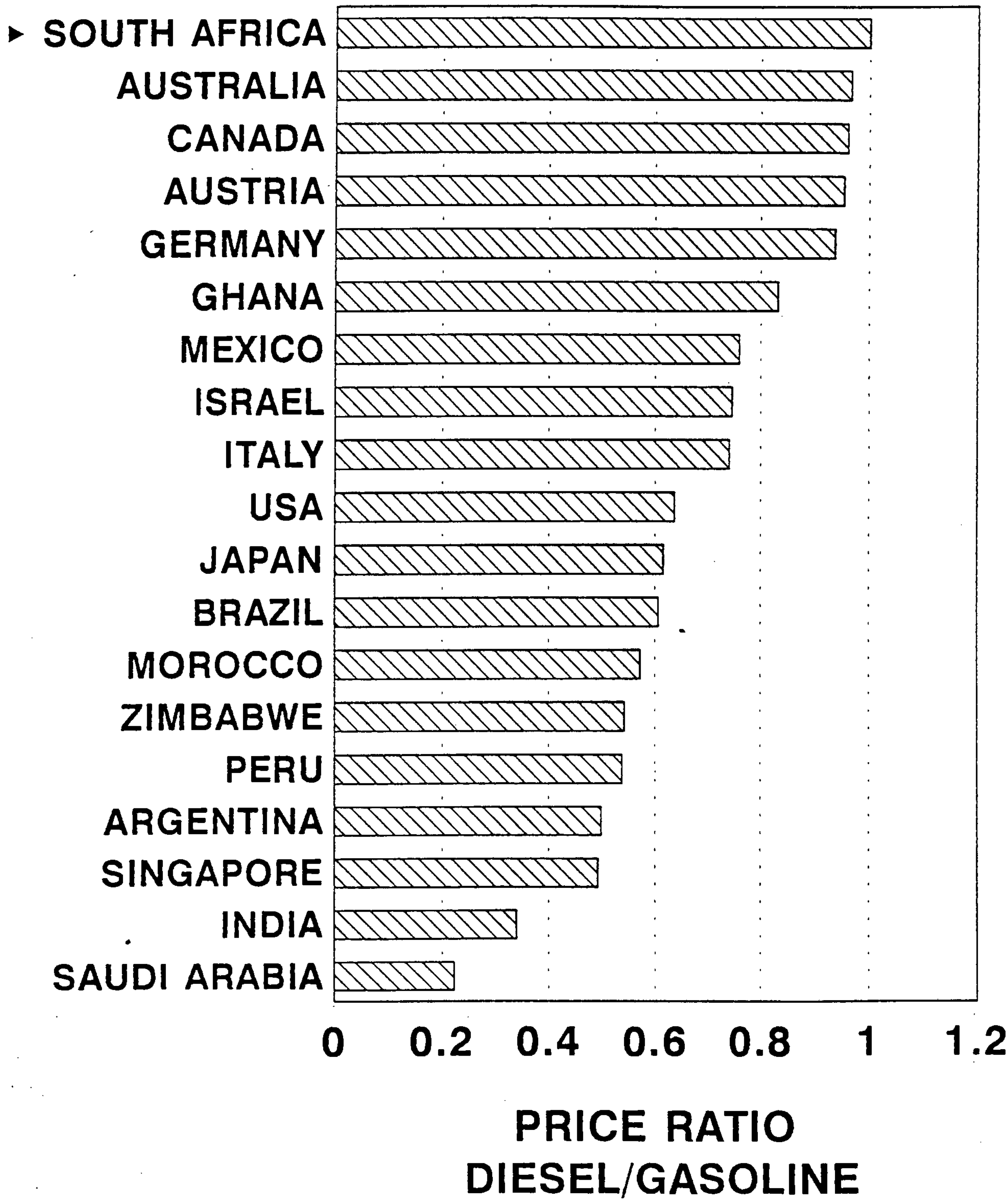

A 5.15

Figure 5.16 International diesel prices relative to South Africa (1990)




SA 5.16

Figure 5.17 Ratio of diesel price to gasoline price

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# ENERGY IN SOUTH AFRICA: A POLICY DISCUSSION DOCUMENT

FINAL REPORT

R K DUTKIEWICZ

JULY 1994